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PREFACE.

The want of a simple Elementary Catechism on the principles of Experimental Science must often have been felt by many who are similarly engaged with myself in the instruction of youth. The following pages have been compiled in the hope that they may, in some degree, supply the lack of a manual of chemistry and its correlative sciences.

In such a work the merit of originality cannot be claimed, both because its subject-matter must necessarily be derived from books already approved, and also because I should deem it presumptuous to substitute my imperfect conclusions for the matured and established deductions of others.

All that I would claim for this little book is originality in its arrangement, simplicity in its statements, and the fact of my experience of its utility as a manual of instruction.

In the hope, therefore, that it may prove similarly useful to others, I venture to commend it to the public.

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QUESTIONS ON CHEMISTRY.

Q. What is Chemistry?

A. It embraces, in general terms, the study of the nature and property of all the materials which enter into the composition of the earth, the sea, and the air.

Q. Upon what kind of proof does chemical science rest?

A. It rests entirely upon experimental demonstration.

Q. What substances form the basis of chemistry?

A. Those which are called *elementary*, *i. e.* substances that are not decomposable.

Q. How many of these substances are at present known?

A. *Sixty-two*; and of these all others are compounded.

Q. Give an instance of a *simple* or *elementary* substance.

A. Iron is a simple substance, because we can only obtain iron from it.

Q. Give an instance of a *compound* body; *i. e.* of that which contains two or more simple substances.

A. A piece of limestone subjected to red heat for a short time loses nearly half its weight and becomes quick-lime — that portion of its bulk which has escaped is carbonic acid; *lime* and *carbonic acid*, therefore, combine to form the substance called limestone, which is thus shown to be of a *compound* quality.

Q. What is the proper term for the chemical separation of a substance?

A. *Chemical decomposition.* And when this has taken place, the original compound substance is said to be decomposed into its *components*, or *constituents.*

Q. Into how many classes are *elementary* substances generally divided?

A. Into two:—*metals* and *non-metallic* substances.

Q. What are the most important of the *metals?*

A. Iron, copper, lead, mercury, silver, gold, magnesium, calcium, and potassium.

Q. Name some of the *non-metallic* substances.

A. Sulphur, phosphorus, carbon, oxygen, hydrogen, nitrogen, &c.

N.B. *Oxygen* and *nitrogen* are the elements existing in the atmosphere: *hydrogen* and *nitrogen* form water.

Q. What is the *physical state* or *condition* of a substance?

A. There are *three* such states, *viz.*: the *solid*, the *fluid* or *liquid*, and the *gaseous.*

Q. Give an example of one substance passing through all these states.

A. *Water:* generally it is fluid, but when sufficiently cooled it becomes solid, and again, when subjected to a sufficient heat, it boils and afterwards becomes steam, which is the gaseous condition of water.

Q. Define *attraction.*

A. There are various kinds of attraction:

1. *Attraction of gravitation; ex. gr.* where a stone falls to the ground in consequence of the earth's attraction.

2. *Magnetic attraction; ex. gr.* the attraction which a magnet has for soft iron.

3. *Electrical attraction;* or the attraction which any perfectly dry substance, such as sealing-wax when sharply rubbed, has for any light substance.

4. *Attraction of cohesion; ex. gr.* the attraction which one perfectly smooth surface has for

another when rubbed together with a circular motion.

5. *Capillary attraction; ex. gr.* a lump of sugar placed in water; the water rises through the sugar by capillary attraction.

Q. What is chemical affinity?

A. That union which sometimes takes place between two or more bodies in such a way as to give rise to a *new* substance, whose properties are different from those of its components.

Q. How are all chemical changes produced?

A. By *affinity*, or *chemical attraction.*

Q. Upon what is the physical state of a substance dependent?

A. Upon its relation to *heat.*

Q. What is the most general effect of heat?

A. (1st.) To cause *expansion* or enlargement.

Q. Give an example of this.

A. A piece of iron or brass when heated will be found to be larger, both in length and width, than when cold; and will, when quite cold, be found to have returned to its original size.

Q. What instrument in common use is made upon this principle?

A. The thermometer.

Q. Explain its construction.

A. A thin hollow glass tube of uniform diameter is made with a hollow glass bulb at one extremity. This bulb, by a peculiar process, is exactly filled with mercury to the top of the bulb; all remaining air is then expelled from the tube, which is then hermetically sealed by the blowpipe. The instrument now consists of the glass tube with the bulb of it filled with mercury. It is now requisite to graduate it for use. This is done either by making marks on the stem, or by fastening the tube to a scale of wood or ivory, all which marks are made according to certain rules.

Q. What are these rules?

A. In England the division of *Fahrenheit* is used. According to this scale the thermometer is graduated into 180 degrees. The zero point is placed 32 degrees below the freezing point of water, the temperature of blood at 98°, and the boiling point at 212°. Below zero the numbers run in an opposite direction and are distinguished from the ordinary degrees by a — sign before them.

Q. What other scale of graduation is used on the Continent and in America?

A. *The centigrade*, which, as its name implies, consists of 100 parts, the zero point being placed at the freezing point of water; the boiling point at the 100th. The scale is continued above and below these points; the points below zero being distinguished by a negative sign.

Q. How are Fahrenheit degrees converted into centigrade?

A. Subtract 32, multiply by 5, and divide by 9.

Q. How are centigrade degrees converted into Fahrenheit?

A. Multiply by 9, divide the product by 5, and add 32.

Q. How are *negative* centigrade degrees converted into negative Fahrenheit?

A. Thus, from the above rule: *ex. gr.* let it be required to convert 15 centigrades into degrees of Fahrenheit.

$$-15 \times \tfrac{9}{5} + 32 = -27 + 32 = +\ 5\ \text{F.}$$

Q. Are any other fluids besides mercury used for thermometers, and why?

A. Yes; *air* and *spirits of wine* are sometimes used. The former, called *differential* thermometers, are used to measure differences of temperatures between two portions of air. The latter, the spirits of wine, are used to measure temperatures below the freezing power of mercury.

Q. Give another instance of *expansion*.

A. That of the metal in the pendulum of a clock.

Q. How is this remedied so as to preserve the regularity of the time-piece?

A. In various ways: the most simple is a rod of metal, to which, instead of a plate of metal being attached, a cylindrical glass jar of mercury is fixed upon a metal stand. When the rod is lengthened by an increase of temperature, the mercury is also expanded, and rising in the cylindrical vessel, elevates the centre of gravity, and thus compensates for the elevation or expansion of the metal rod.

Q. To what natural phenomena does the expansibility of air by heat give rise?

A. To that of the winds; more particularly the *trade winds.*

Q. Why?

A. Because the rays of the sun falling less obliquely upon the earth near the tropics, occasion the earth to be more heated there than upon any other part: this heat is imparted to the lower stratum of air in those regions, and this being expanded, rises, giving place to colder air streaming in laterally from the more temperate regions, north and south; and this in turn becoming warm, ascends, making place for another current. This successive motion in the air originates the winds, which vary in their regularity according to the part of the earth's surface in which they are found.

Q. To what practical purpose is this theory of expansion applicable?

A. To that of natural and artificial ventilation, and to the action of chimneys.

Q. How is it shown in ventilation?

A. In a mine, for instance, where ventilation is contrived by means of two shafts, or one divided down the middle; and these are so arranged, that air drawn down one shaft or channel traverses the extent of the mine below before it escapes by the other. A fire kept up in one of the shafts rarefies the air, and causes an ascending current which carries with it the impurities of the air.

Q. How is expansion shown in the action of chimneys?

A. When the chimney is heated, the air expands, and a portion is driven out; the weight of the air being less than that of the outer atmosphere, equilibrium ceases, the warmer and lighter air is forced up from below, and a constant current maintained, so long as the sides of the chimney are hotter than the outside air.

Q. What is meant by the *conduction* or *penetration* of heat?

A. Its power of passing through a substance so as entirely to pervade every part of it.

Q. Give an instance of good and bad conductors of heat.

A. *Iron* and *glass*. If a rod of each be held in a flame, the iron soon becomes too hot to be held, while the glass at the same heat can be easily held by the hand close to the red-hot portion.

Iron is therefore said to be a good conductor, while *glass* is a bad one.

Almost all metals are good conductors, while glass, wood, water, air, &c. are very bad ones.

Q. If water and other liquids are bad conductors, how is it that they can be so rapidly heated?

A. This can be accounted for by the fact that the water at the bottom of the vessel, as it is heated becomes lighter, and tends to the surface, and thus heat soon becomes general through the whole fluid.

Q. How does heat change the condition of substances to which it is applied?

A. By certain fixed and invariable laws. Certain degrees of temperature, determined by the thermometer, are found invariably to melt various substances, either metallic or non-metallic. *Ex. gr.*

Ice	melts at	32°
Wax	"	140°
Sulphur	"	238°
Tin	"	442°
Lead	"	612°
Spirit of Wine	"	173°
Water	boils at	212°

Q. What is *latent* heat?

A. The heat which a body would receive or lose under certain conditions, without affecting the senses, is called latent heat.

A body may receive a very large increase of heat without any increased sense of warmth being produced by it; and again, this body may lose a considerable quantity of heat without causing any diminished sense of warmth.

If equal weights of water, for instance, one at a low and the other at a high temperature, be mixed, the temperature of the mixture will be the mean of the two temperatures. If the same experiment be repeated with snow or pounded ice at the same temperature as the water, the temperature of the whole will be only that of the lowest degree taken. The snow or ice will, however, have melted. In this last experiment, as much heat has apparently been lost as could have raised a quantity of water equal to that of the ice to a very high temperature. This is general; for when a solid becomes a liquid, a certain definite amount of heat becomes latent; and on the contrary, when a liquid becomes a solid, heat to a proportionate extent is given out. Of course latent heat varies in various substances.

Q. What is *distillation?*

A. The separating substances which rise in vapour at different temperatures; or, the separating a volatile liquid from any substance which is not volatile.

Q. Describe a simple distilling apparatus.

A. Every such apparatus must have a *boiler*, in which the vapour is raised; and a *condenser*, in which it returns to the liquid or solid state. A common retort and receiver immersed in water as a condenser, with a spirit lamp or charcoal fire under the retort, is the simplest apparatus for distilling.

Q. What is *evaporation?*

A. The disappearance of a liquid, or a portion of it, under certain conditions of the atmosphere, and of heat.

Q. At what temperature do liquids generally evaporate?

A. At a temperature below their boiling point; and, in this case, the evaporation takes place entirely from the surface.

Q. Do any liquids entirely evaporate or dry up, when exposed to the air?

A. Yes: water or spirits of wine, when exposed in an open vessel at the temperature of the air, gradually dry up and disappear.

Q. What is the condition of *maximum density?*

A. That state of density which a vapour cannot pass without losing its gaseous condition, and becoming liquid.

Q. Upon what does the point of maximum density depend?

A. Upon the temperature; as that rises, the point of maximum density increases.

Vapour of water exists at all times in the atmosphere, and there performs a very important part in the arrangements of nature.

Q. What is meant by the term "capacity for heat?"

A. Different substances, though of equal weight, and having the same temperature, require different amounts of heat to raise them to a given temperature. Thus, if equal weights of water, oil, and quicksilver be taken, and it be required to raise them to equal degrees of temperature, it will be found that less real heat will be required by the oil than by the water, and much less by the quicksilver than by either of the others.

Again, if equal weights of hot water and cold oil be shaken together, their temperature will then be found higher than the mean temperature of the two; and if cold water and hot oil be used, their temperature will be found lower than that of their mean.

Water, therefore, has the greatest capacity for heat, oil less, and quicksilver least of the three.

Q. What is meant by the specific heat of a body?

A. The numbers which express the relation of the different capacities for heat of different bodies; thus, the *specific heat* of oil is $\frac{20}{40}$.

Q. What are the sources of heat?

A. The greatest source of heat is the sun. Its rays, passing through the air, which is not heated by them, reach the earth's surface and increase its temperature: this heat rises from the surface of the earth and expands in different parts of the earth and seasons, and by this unequal heating currents of air are formed, and this is the origin of winds.

Next to the sun, the greatest source of heat is supposed to exist in the interior of the earth.

Q. What are the other sources of heat?

A. They are very numerous, but the principal may be divided into two groups, *viz. mechanical motion*, and *chemical combination*.

Q. How is heat caused by mechanical motion?

A. By *friction* of machinery, &c., or by blows.

Q. And how by chemical combination?

A. By the effects of *combustion* and *animal respiration*.

Q. What is *magnetism*?

A. A *species* of force peculiar to iron ore, by which one particle of iron is observed to attract another particle at various distances.

Q. Why do you term it a *species* of force?

A. Because it is not in itself among the dynamic or active forces, but only directs them; and, therefore, requires motion to be added from some other source.

Q. From whence is the term *magnetism* derived?

A. From the Greek word *μαγνης*, or magnesian stone, known by the Greeks to possess the power of attraction.

The terms *magnet* and *magnetism* are both used; the one to define the mineral substance itself, the other the power supposed to reside in it.

Q. What is *magnetic attraction*?

A. The power, or force in operation.

Q. What is magnetic polarity?

A. If a piece of magnetic iron ore be examined, it will be found that only certain points on its surface attract iron particles with any degree of force. These attractive

points are called poles, and the loadstone itself is said to possess *magnetic polarity.*

Q. What is an *artificial magnet?*

A. If a pole of a natural loadstone be rubbed in a particular manner on a bar of steel, the properties of the magnet will be communicated to the steel, and will render it as effective as the loadstone itself. The attractive force, however, will be the greatest at two points, at the ends of the bar, and the least in the centre. This bar of steel will form an *artificial magnet.*

Q. What invariable property of the magnet is observed when suspended at its centre so as to turn freely on that point?

A. It will then be observed that the magnetic mass will only rest in one position, *viz.*: one end pointing nearly north, and the other nearly south. These poles of the magnet are distinguished as the *north* and *south* pole of the bar. A proof of this may be given by plunging a piece of magnetic ore into fine iron or steel filings; the particles will then be attracted and collected in the greatest number on two opposite points of the magnet.

Q. If one magnet be suspended within the influence of another, what results will be observed?

A. When a north magnetic pole, for instance, is presented to a south pole, or *vice versâ,* attraction takes place between them; the ends of the bars approach, and if near enough will adhere; but if a north pole be brought near to another north pole, or a south to a south, repulsion, and not attraction, ensues. Hence a general rule may be established: that poles of an *opposite* name *attract,* but of a *similar* name *repel* each other.

Q. What is the plane of the *magnetic* meridian?

A. It is a plane perpendicular to the horizon, and passing through the poles of the magnet when in its polar or directive position.

Q. What is the *variation* or *declination* of the magnet?

A. The angle made between the line or direction of

the magnetic meridian, and the line of the true meridian of the place in which the magnet is hung.

Q. What are the variations of declination?

A. The divergence of the needle from the true north and south, not only in different places, but even in the same place in daily and yearly changes.

It has been ascertained that through a long course of years, till 1818, the declination was first eastward, then due north and south, and afterwards westerly, and since that year it has been gradually diminishing.

Q. How is iron said to be magnetised by *induction* or *influence?*

A. When it is brought within the influence of a magnet, and itself receives some portion of that magnet's power. Thus, a piece of soft iron brought in contact with a magnetic pole immediately acquires an attractive power.

Q. Is this attractive power lasting?

A. No; for as soon as the magnetic influence is withdrawn, the iron ceases to have any attractive power.

Q. What effect is produced when steel is substituted for iron?

A. Then the inductive action is much slower at first; in fact, it is hardly perceptible till some time has elapsed, and when its action has been ascertained, and the steel bar is removed from the magnet, the bar will be found to have retained a portion of the induced magnetism.

This power remains, and renders the artificial magnet almost as effectual and permanent as the real.

Q. What technical name is given to this resistance of steel at first to magnetic influence, and its subsequent retention of it?

A. It is called *specific coercive power.*

Q. What rule regulates the induction of magnetic polarity?

A. That the pole produced is always of the opposite name to that which produced it. A north pole, therefore,

would produce south polarity, and a south pole north polarity.

Thus, if the *north* pole of a magnet were surrounded by a number of other magnets, their south poles would be in the nearest contact with it, and their north poles the farthest removed.

This inductive action may be continued with like effect through another series of magnets, and again through others, the intensity of the force diminishing only as the distance from the original magnet increases.

Q. What instruments are used to ascertain whether a substance has polarity or not; and also to discover the kind of force in operation?

A. The horizontal, astatic, and vertical needles are instruments for this purpose.

Q. Describe them.

A. The *horizontal* needle is simply a thin magnetic bar, or cylinder, which is finely balanced on a point at its centre, upon which it can move freely in a horizontal plane.

The *astatic* needle consists of two equal and similar bars or cylinders, fixed parallel to each other upon one centre with their opposite north and south poles one immediately over the other.

The force of the needles in this combination is almost neutralised.

The *vertical* needle is a similar instrument to the horizontal, but is hung vertically instead of horizontally.

These instruments are also known by the name of *magnetoscopes.*

Q. Is there any other kind of magnetoscope?

A. Yes; the most simple instrument of this kind is a small horizontal needle about an inch long, set upon a fine point and agate centre in a small wood or glass case. The centre is so made in the shape of an inverted V, that the needle may easily mark the dip of either pole as well as turn in a horizontal plane.

Q. How can the presence of polarity acting upon the magnetoscope be determined?

A. If the instrument be moved gently along the plane

of any substance without any sensible deflection on the part of the needle, the substance may be considered as non-magnetic; if, on the contrary, the needle be agitated or deflected to any particular point, then the substance is proved to be magnetic; and if certain points attract one of the poles of the needle and repel the other, then we conclude that the substance possesses both magnetism and polarity.

Q. Are magnetic attraction and repulsion influenced by the interposition of substances that have no magnetic property?

A. In no degree; for thick glass, some metals and woods that have no magnetic properties may be placed between a magnet and any iron under its influence; and no alteration in its attractive power will be perceptible.

Q. Show that one kind of polarity cannot exist without the other.

A. If a magnetised bar of steel be broken in the middle, or at some point where its magnetic power is neutral, each of the broken ends becomes an opposite pole, so that each piece forms a perfect magnet; and if these bars were again broken into a series of pieces, each piece would become a magnet with a north and south pole.

This fact is a leading principle in electrical science.

Q. Does iron react upon a magnet?

A. Yes; often to such an extent as to neutralise its attractive force. Thus, if a piece of soft iron were suspended from one end of a delicate balance, to the other end of which a non-magnetic counterpoise is attached, and a strongly magnetic bar placed under the suspended iron, the iron would be immediately attracted, and the equilibrium of the balance destroyed; but if another piece of soft iron of equal breadth and thickness with the magnet be now approached to it, the iron attached to the balance will be released from the magnet, and the balance will resume its equipoise.

Q. What is *electro-magnetism?*

A. It is that property of the natural and artificial magnets by which, under certain conditions, they arrange

themselves in a relative position to a wire which conducts a current of voltaic electricity.

Q. What is a *voltaic circle?*

A. If two plates, the one of zinc and the other of copper, are placed near each other in a vessel of acid diluted in a proper degree, and these plates be connected with each other by a continuous wire, an electro-chemical action will take place during the solution of the zinc in the acid, so that a current of electricity will pass from the zinc to the copper plate, and thence along the wire till it again returns to the zinc plate. This circuit is called a voltaic circle.

Q. Is there any other more powerful voltaic combination besides that of zinc and copper?

Yes; that of platinum foil and zinc coated with mercury; and the acids, nitric and sulphuric.

Q. How are the ordinary voltaic batteries constructed, and what is the arrangement of the wires in them?

A. The batteries are arranged in a series of cells, and the wires so arranged as to act at any given spot.

Various directions may be given to this current, according to certain rules, which belong to a peculiar branch of physical science, which would be out of place in an elementary work.

Q. Can iron and steel be magnetised by the electrical current?

A. Yes; and to so great a degree as to be capable of sustaining a considerable weight.

Q. When electrical and magnetic forces are both in operation, as in the action of the voltaic circle, what is their direction with regard to each other?

A. One force is exerted at right angles to the other; and, by certain arrangements of the magnetic current, any direction may be given to the object, and it may be rendered magnetic as effectually as if brought in contact with an ordinary magnet.

Q. In what instrument is this force commonly employed, and how?

A. In the electro-magnet, which consists of a cylin-

drical piece of soft iron bent into a horse-shoe shape and bound round with successive coils of copper wire, covered with some bad conducting material, such as silk, in order to insulate as much as possible the metallic communication of one coil with another. The ends of these coils are brought down nearly to each side of the horse-shoe iron, and are then turned off into a point on either side.

When the instrument is in use, these points are connected with a strong voltaic battery, such as that which has been mentioned, of platinum foil and zinc, coated with mercury, and merged in nitric and sulphuric acids. And if then a piece of soft iron, called a keeper, be placed across the projecting poles of the electro-magnet, it will be held fast, with such a power that hundreds of pounds may be suspended from it.

Q. Are there other metals besides iron which are magnetic?

A. Yes; the metal called nickel is, next to iron, considered to be the most magnetic, and not only attracted by and attracting the magnet, but also possessing definite polarity.

Hammered brass also possesses a considerable amount of magnetic force; and also in a lesser degree, rhodium, iridium, and antimony, when heated, are magnetic.

Q. What has been the result of experiments to determine the question of "universal magnetism."

A. Various experiments have been tried at different times to ascertain whether a certain degree of magnetism might not be discovered in almost every natural substance. In one instance, by suspending needles between the poles of opposite magnets, and causing them to vibrate beyond, and then within the magnetic influence, it was found that the magnetic poles decreased the vibrations, and that all the substances experimented upon settled at last in the direction of the poles.

It was inferred from these experiments, either that iron was present in some degree in every substance, or that each substance possessed some magnetic power of its own.

Another experiment was performed by enclosing several oxides of iron in thin paper cases, and then suspending them at a certain distance from the pole of a magnet; the result was, that the oxides, instead of assuming a position in the line of the pole of the magnet, as soft iron would have done, stood at right angles to the line of the pole, so that in this experiment, the line of magnetism was inferred to be across the direction of the poles.

Another and very important experiment of Arágo determined the fact, that the influence of substances on a vibrating magnetic bar tended to bring the needle more or less rapidly to rest, metallic substances especially, and that this result was obtained by diminishing the range of the oscillations without altering the time of each stroke.

Q. What effect has heat upon electrical currents in metallic substances?

A. It causes them to flow between the heated and cooled parts so as to influence the magnetic needle.

Q. Is the action of this current increased in metals that have been soldered together?

A. Yes; more particularly when antimony and bismuth have been united.

Q. At what degree of heat does the force of these currents seem to decline?

A. After attaining about 120° of Fahrenheit, the metal appears to be more generally heated, and the direction of the current becoming less definite, decreases in intensity.

Q. Into what *two* classes does Faraday divide magnetic substances?

A. Into *paramagnetic* and *diamagnetic*.

Q. What is a paramagnetic substance?

A. That which is attracted by both poles of the horseshoe magnet.

If a small iron bar be hung by some badly conducting substance, such as silk, between the poles of the magnet, so that it can move in a horizontal plane, it will arrange

itself in a straight line parallel to the straight line which joins the poles, and will have a south pole at the end nearest the magnetic north pole, and a north pole at the end nearest the magnetic south pole.

Q. What is a diamagnetic substance?

A. Any substance through which a magnetic force passes without rendering the substance itself magnetic.

It has been ascertained that a ray of light, passing through a body, say a cube of glass, placed between the poles of an electro-magnet, becomes bent, or turned aside from its first course, by magnetic action.

Q. What is the result of the combination of diamagnetic and paramagnetic bodies?

A. That their peculiar properties are destroyed; and that where iron is found, even in the smallest quantities, the magnetic power is more or less dominant. Thus, though glass is not itself magnetic, yet in green bottle glass, and in some kinds of crown glass, magnetism is known to exist, in consequence of iron being a component part of such kind of glass.

Q. How are metallic bodies discovered to be magnetic or not?

A. If magnetic, they could, by the application of the electro-magnet, be made to point in an axial direction; if they are diamagnetic, they will assume an equatorial position. If near the poles, they would, if magnetic bodies, be attracted, but if diamagnetic, then they would be repelled.

Q. What metal has the greatest diamagnetic power?

A. Bismuth, which has the least magneto-electric energy of all the metals. Antimony is also strongly diamagnetic.

Q. What results have been derived from Faraday's experiments as to the magnetic condition of gases?

A. On making soap bubbles with the gas which he wished to investigate, and bringing them near to the poles of a magnet, Faraday discovered that soap and water alone is hardly diamagnetic. A bubble filled with

oxygen was strongly attracted by the magnet. All other gases in the air are diamagnetic, and suffer repulsion.

Q. Under what two forms may magnetism be considered as a universal power?

A. As *magnetic* or *diamagnetic*; under the former, substances such as iron are *attracted;* under the latter, as in the case of bismuth, they are repelled: and under the one or other of these conditions, all matter may be said to be susceptible of magnetic influence.

Q. What are the magnetic and diamagnetic substances according to Faraday's recent discoveries?

A. Iron, nickel, cobalt, manganese, chromium, cerium, titanium, palladium, platinum, and osmium are all *magnetic.*

Bismuth, antimony, zinc, tin, cadmium, sodium, mercury, lead, silver, copper, gold, arsenic, uranium, rhodium, iridium, and tungsten are all *diamagnetic.*

As the construction and use of magnetic instruments could not be sufficiently explained without a number of diagrams, and as it is not thought expedient to introduce any into so elementary a work as the present, the student is necessarily referred to works which embrace the whole subject of magnetism, and illustrate it both by experiment and diagram.

Q. What is electricity?

A. Electricity may be defined as a certain chemical action pervading nature, and seemingly transmitted through certain bodies in a *current,* according to certain ascertained laws.

Q. From what is the term electricity derived?

A. From the Greek word *ηλεκτρον,* which signifies amber. That substance was known to the ancients to possess strongly attractive properties when subjected to friction.

Q. What other means besides friction are used to produce electricity?

A. Heat, chemical action, and pressure, will all produce it.

Q. What phenomenon is observed in electricity which is not to be found in magnetism?

A. The effect of *discharge*, which instantly takes place when any electrified body is made to communicate with the earth by any one of the substances known to be a conductor of electricity.

Q. What effects are common to magnetism and electricity?

A. Attraction and repulsion. The induction of soft iron in magnetism has a counterpart in electricity when a body that has been electrified disturbs or polarizes the particles of all surrounding substances in the same manner, causing a condition opposite to its own in the nearer portions, and a *similar* condition in the parts more remote.

Q. What are the substances which yield electricity called?

A. *Electrics.*

Q. When is a substance said to be *electrified?*

A. When, by the process of friction, it has been put into a condition to attract other substances.

Q. What is this process of friction called?

A. *Electrical excitation;* and the attractive force is called *electrical attraction.*

Q. What are the contrivances for exhibiting electrical attraction called?

A. *Electroscopes;* and those which are made for measuring the power itself are called *electrometers.*

Q. How is *electrical excitation* produced?

A. By rubbing a stick of sealing-wax, or a dry glass tube, for instance, with a warm piece of flannel or silk.

Q. What is the action of this electrified body?

A. When brought near to any light substance, such as a feather, a piece of alder pith, or a fragment of metallic leaf, it first attracts such objects, and then, when they become electrified, they are repelled by the sealing-wax; and if more than one object be electrified a mutual repulsion takes place between each.

Q. How many kinds of electricity are there?

A. *Two; positive* and *negative.*

Q. Define these terms.

A. For the purpose of distinction the term *positive* or *vitreous* is applied to the kind of electricity manifested by glass; and the term *negative,* or *resinous,* to that which is manifested in the action of shell-lac, and bodies of that class.

The terms plus, +, and minus, −, are affixed to these qualities merely to simplify the comprehension of the subject, and to facilitate the working of experiments.

Q. In what condition does *repulsion* take place, and why?

A. In the *positive;* because each body being repellent, the particles of that which is in excess repel the particles in the other while electric action lasts.

Q. What condition takes place in *negative* electricity; and why?

A. That of *attraction;* because negative or opposite electricities tend to unite: the electric force of the plus exceeding that of the minus, and causing the excess in the one to supply its deficiency in the other.

Q. What rule may be deduced from these considerations?

A. That bodies *similarly* electrified *repel* one another; and bodies electrified in *different* ways *attract* each other.

Q. What are *idio*-electrical substances?

A. Those from which electrical properties are readily obtained by friction.

Q. Name some of these electrical bodies.

A. Shell-lac (or sealing-wax), amber, brimstone, jet.
All resinous bodies, including pitch and wax.
All gums.
Gun-cotton.
Glass, and all vitrified substances.
Crystalline and silicious substances.
Gems and stones.
Silk of every kind.

Hair, wool, feathers, and paper.
Turpentine, and some oils.
Dry gases.
Atmospheric air.

Q. What is *electrical conduction?*

A. A species of electrical action by which the electricity in one body is conveyed to, and retained in, another in which it could not be primarily excited.

Q. What are conductors of electricity?

A. Those substances which freely convey the electric fluid from one part of their surface to another.

All *electric* substances are *non-conductors* or *insulators;* and all *non-electric* substances transmit or conduct electricity.

Q. Name some of the principal conducting substances.

A. Metals are the best conductors.
Metallic ores are also good.
Acids.
Water, and all humid substances.
Vapours, flame, smoke.
Living and animal matter.
Glass, silk, shell-lac are among the worst conductors; and between these substances there are many bodies of various conducting power.

The earth is the great receiver and conductor of electricity.

Q. What are *non-conducting*, or *insulating* substances?

A. Those which, at the best, are but poor conductors; the difference between conductors and non-conductors being more one of degree than of kind.

Q. What are the best non-conducting substances?

A. Sealing-wax, gum-lac, gutta-percha, resin, sulphur, glass, porcelain, marble, and atmospheric air.

Q. What is *electrical induction?*

A. The influence of electrically excited bodies upon neutral conducting bodies at various distances.

Q. How does electrical induction act upon a neutral body?

A. If two small cylinders of metal, flat at the ends, be insulated upon supports of varnished glass, and placed in a line with each other so that the flat extremity of one shall be within an inch or more of the flat extremity of the other, and if an electric charge be applied to the end of one of these cylinders, the left hand one for instance, and a metallic leaf, or other light substance, be applied near the further end of the right hand cylinder, it will be immediately drawn towards it, and this attraction will be apparent, though in a less degree, the nearer it approaches to the left hand cylinder, from whence the charge was given.

If this left hand cylinder be removed, the influence in the right hand one ceases, showing that its electrified condition was merely *induced*, or temporary, and depending entirely upon the influence of the charged cylinder.

The *attraction* manifested in this experiment might, by the application of the electric charge at a different point, be converted into *repulsion*, and thus we see that the electrical action, called *induction*, is essential to the conditions both of attraction and repulsion.

It may, indeed, be said that the bodies are prepared by induction for the subsequent condition of attraction or repulsion in which they may be placed.

Q. Does inductive action thus taking place through air produce similar effects when any other electric substances are interposed?

A. Yes: with this difference, however, that some electrical substances are more favourable to this influence than others.

Q. What is this capacity in various bodies called?

A. Faraday, who made the discovery, calls it "*Specific inductive capacity.*"

Q. Does electrical action pervade every part of a body?

A. No! it does not penetrate beyond the surfaces of bodies. If a ball were charged with positive electricity the effect would be entirely upon its exterior. All expe-

riments have hitherto failed to detect electricity in the interior of a substance, whatever its shape may be.

Even on the surface electric force is not equally distributed. The shape of the body itself, and its position with regard to surrounding objects, will affect the degrees of electric force. A body whose shape presents any projections or points is most susceptible of polarity in that part.

Q. Define *Polarity.*

A. It is such an arrangement of force as enables the same particle to exert opposite powers in different parts.

Q. What other sources of electrical action are there besides that caused by *friction?*

A. We have said that heat, chemical action, and pressure will all produce electrical action.

Heat will produce it by chemical change of form and temperature.

Also from changes of temperature only.

Chemical action alone will produce it.

Contact, either with or without pressure, will also produce electricity.

Contact of *metals* and *fluids,* as in the case of the *Voltaic pile,* is a very powerful source of electrical excitation.

This electrical force is found also in some kinds of fish in a strong degree.

And, lastly, *magnetic influences,* either natural or artificial, excite it in a powerful manner when brought to act on metallic wires.

Q. After thus stating the principles of electricity, it will be necessary to give some account of their application; in what manner, therefore, is electricity *excited* and *applied?*

A. By means of *electrical machines.*

Q. What machines are in most common use when *friction* is employed to excite electricity?

A. These machines are of two kinds, but the principle is the same in both.

Q. Describe them.

A. They both consist of some electric substance to be excited; of a rubber or cushion by which this condition is effected; and of an insulated conductor to receive the excited electricity.

Q. What is the cylindrical machine?

A. It consists of a glass cylinder, mounted horizontally upon a wooden stand, so arranged that the cylinder, with a crank and handle, by which it can be turned, can be worked easily in the frame. A leather cushion is made to press, by a spring, upon one side of the cylinder, and a large metal conducting body armed with a number of points next the cylinder occupies the other side. The cushion and the conductor are insulated by glass supports, and on the upper edge of the cushion is attached a piece of silk long enough to cover half the cylinder. On the cushion is spread a quantity of amalgam made of one part of tin, one of zinc, and six of mercury, mixed with grease, in order to excite the glass, which it does in a most powerful manner.

The cylinder, as it is turned, is charged by friction against the rubber, and as quickly discharged by the row of points attached to the conductor. This conductor being insulated, the electricity imparted to it can only be communicated by contact with other insulated bodies.

The greatest effect is given when the rubber is connected by a chain or wire with the earth.

Q. How is this machine arranged when *positive* electricity is required?

A. The substance to be electrified is approached to the conductor, and the cushion is connected with the earth by means of the chain or wire above mentioned.

Q. How is it arranged when *negative* electricity is required?

A. This arrangement is reversed: the body to be charged is presented to the negative conductor, or cushion, and the positive conductor, or row of points, is connected with the earth, so as to relieve the surface of the cylinder from electricity, and enable it to produce an uninterrupted

friction in the rubber, and thus a constant supply of negative electricity to the cushion.

Q. What is the other form of electrical machines?

A. It consists of a circular disc of plate glass moving upon an axis, and provided with two cushions or rubbers, one at the top and the other at the bottom of the frame, covered with amalgam, and through which the plate moves with considerable friction. The conductor is insulated, as in the cylindrical machine, and the rubbers are connected with the ground.

Where great power is required this machine is superior to the other.

In the use of all electrical machines great care must be taken to preserve every part of the instrument free from the slightest amount of moisture.

Q. What other kinds of electrical machines are there?

A. One called the *hydro-electric*. The action of this machine depends upon the excitation of particles of water driven by steam through very small apertures. Its discovery was owing to a leak in the boiler of an engine, from whence a considerable amount of electric force was found to issue.

The principle of this electrical condition is that friction is caused by the condensed particles of water driven by the steam through the jets, or apertures; the water supplying the place of the glass plate in the ordinary machines, and the wooden jets and pipes acting as the rubber, while the friction of the passing steam is the source of the electricity.

The electricity generated by this engine is very great in quantity, but is not so intense as that produced by some other machines.

Q. What is the *electrophorus?*

A. An instrument invented by Volta, and capable of retaining electricity for a considerable time. It consists of a circular plate of shell-lac, or other resinous substance, bound round its edge by a stout wire. A brass disc, a little less in diameter than the plate, and fitted with an insulating glass handle, is placed upon the shell-lac, after

it has been excited by the friction of a piece of warm fur or silk handkerchief. The brass plate is then touched with the finger and gives a spark of *negative* electricity. If the cover be raised it will be found strongly charged by induction with *positive* electricity, and the sparks thus obtained may be drawn from it as often as required.

The reason of this is that the shell-lac loses nothing of its electricity in the operation; when the metal plate in contact with it is touched, the negative electricity is removed from it; and when the metal plate is raised by the insulating handle it is charged with positive electricity, because the negative fluid has been removed from it, while the positive fluid in it remains by the attraction of the negative fluid in the shell-lac.

Q. What other electrical machines are there which do not depend upon friction?

A. The *dry electrical pile*, the *voltaic series*, and the *magnetic coil;* these instruments are employed in various electrical researches where motion is concerned, but are of little use where considerable stationary power is required.

Q. What is the *electrical phial*, or *Leyden jar*.

A. It is a thin glass jar, coated both inside and out with tin foil, up to within a small portion of the top, where the glass is left uncovered for the purpose of insulation. A closely fitting wooden stopper is inserted in the mouth of the jar, through which a metallic rod, terminating in a metallic ball or knob, is passed down to the bottom of the jar, where it rests upon a socket of wood placed on the tin foil.

Q. What is the use of the Leyden jar?

A. To *accumulate* electricity.

Q. How is this effected?

A. The outside of the jar is connected with the earth; the knob at the end of the metallic rod is put in contact with the conductor of an electrical machine; a succession of sparks enter the jar, and, in time, fill it with *positive* electricity. On the principle of induction, positive electricity is then driven off the outside of the jar, and it

becomes charged with *negative* electricity. In this manner electricity is *accumulated* for any experiments requiring a great amount of electric force.. The whole amount thus accumulated can be discharged from the jar by applying a metal rod, made for the purpose, and called a *discharging rod.*

Q. What is the shape of this rod, and how is it used?

A. The rod consists of a glass handle attached to a curved metal rod, terminated at each extremity by a brass knob. When brought into use, one knob is applied to the metal knob on the top of the Leyden jar, and the other knob is brought down in contact with the tin foil on the outside of the jar.

Q. What is the meaning of the term *electrical current?*

A. It is a term employed to describe the action of electricity in some certain direction. If, for instance, a piece of zinc and a piece of platinum are placed in diluted sulphuric acid, electrical action ensues; the zinc becomes negative, the platinum positive, and if a metallic communication be arranged between these two plates, electrical discharge ensues. One such discharge follows another in instantaneous succession, and this apparently continuous action is called an *electrical current.*

It must be clearly understood that this term does not imply any palpable or bodily substance. The current itself is invisible, it is only its effect that can be felt or seen.

Q. What is the *electrical battery?*

A. It is an arrangement of various forms of apparatus upon the same principle, and for the purpose of producing the same effects. The voltaic pile, the crown of cups, and the battery formed by a number of Leyden jars arranged in a certain order, are all examples of this kind of apparatus.

Q. What is the voltaic pile?

A. An instrument invented by Volta to intensify the electric current.

It consists of a plate of zinc, upon which is laid a cloth, rather smaller than the plate: this cloth is saturated with

any acid, or liquid that can excite chemical action upon the zinc. A plate of copper or platinum is then placed upon the cloth, then a second piece of zinc, another cloth, and another plate of metal, until a pile of about twenty alternate layers is accumulated.

If the two end plates be touched with wet hands, a considerable shock will be experienced; and if the number of layers be much increased, the shock will be most powerful.

Q. What is the *crown* of *cups?*

A. Another instrument of Volta's, the same in principle as the one just described.

A number of cups or glasses are arranged in a row, or circle, each containing a zinc and copper or platinum plate, and a portion of exciting liquid. The copper of the first cup is connected with the zinc of the second cup, the copper of the second with the zinc of the third, and so on for the whole series. If a communication is established between the first and last plates of the series, a discharge takes place, as in the former apparatus.

Q. What is the electric battery formed by an arrangement of Leyden jars?

A. A number of jars, similar to the one already described as the "Leyden jar," are placed on a tray lined with tin-foil, which serves as a common conducting base for the outer coating of each jar; the inner coatings communicate together by means of metal rods, which connect the various knobs of the jars together. The battery is discharged by means of a chain, which has one end attached to the tin-foil of the tray, and the other end to the knob of a discharging rod.

Q. What general rule may be laid down for determining the course of the electric current in the various instruments just described?

A. That the current in every battery in an active state starts from the metal influenced by the acid, passes through the liquid to the second metal or conducting body, and returns by the wire or other means of communication.

Q. How are electrical quantities measured?
A. By instruments called *electrometers.*

Q. What is the *quadrant electrometer?*
A. It consists of a small pith ball attached to the end of a light reed stem; the other end of the stem works on an axis attached to a vertical conducting rod, which is terminated at its upper end in a metal ball, and at its lower end in a similar ball and point, by which the instrument when in use, is attached to the conductor, or rod of an electrical jar. A graduated quadrant is fixed to the upper end of this rod, from the centre of which the reed stem works.

When the instrument is attached to the electrical jar, or any other machine whose amount of electricity it is required to measure, the reed stem and pith ball rising along the graduated scale mark on its index the degree of electricity in the jar.

Q. What other *electrometers* are there?
A. Several; such as *James and Cuthbertson's discharging* electrometers; *Cavendish's electrometer;* the *balance of torsion;* the *hydrostatic electrometer;* and the *scale-beam* electrometer. As the use of these instruments can only be understood by diagrams, they are only mentioned by name in this catechism.

Q. We have spoken of the electric current; what has been the computed velocity of an electrical discharge?
A. The discharge through a wire half a mile long, was computed at the rate of 576,000 miles in a second of time.

Q. What *mechanical* effects are observable in the transmission of electricity?
A. The frequent rending asunder of the body through which the shock is transmitted; sometimes the metals are expanded or bent.

When electricity passes through imperfect conductors, their particles become separated by expansion, while other particles that surround them are compressed. This, together with the collapse of the air, causes the snapping sound of the electric spark.

Q. What phenomenon is observable when an electrical discharge passes through insulating, or imperfectly conducting matter.

A. The production of heat and light.

When the electric spark is obtained in oil, ether, or spirits of wine, a brilliant light is produced, accompanied by considerable heat.

Many substances can also be set on fire by the electric spark; while, by the action of a powerful voltaic battery discharged through points of hard charcoal attached to wires connected with the opposite extremes of the battery, diamonds, platina, and other substances most difficult of fusion by ordinary means, are immediately melted.

Q. What other agency besides mechanical action, accompanies electricity?

A. That of *chemical* action.

Q. In what manner is this displayed?

A. In the *decomposition* of certain substances.

The heat produced by electricity can convert metals into oxides, while the chemical decomposition produced by electricity will affect the oxides, and restore the metal to its former condition.

Vermilion — a compound of sulphur and mercury — can by electricity, be decomposed, so that the mercury can be reproduced in its metallic state.

So, also, water can be converted into hydrogen and oxygen gases.

Sparks discharged for some time through the air of a closed receiver, cause the two gases in the air to combine and to form nitric acid.

Q. In what respects are *electricity* and *lightning* identical?

A. Franklin, who was the first to obtain electricity from the clouds by means of a kite with a pointed wire fixed to it, and by insulating the cord with a portion of silk line attached to its lower extremity, proves the identity of electricity and lightning, in the following particulars:—"First, in giving light; second, the colour of the light; third, its crooked direction; fourth, its swift

motion; fifth, being conducted by metals; sixth, crack or noise in exploding; seventh, subsistence in water or ice; eighth, rending bodies it passes through; ninth, destroying animals; tenth, melting metals; eleventh, firing inflammable substances; twelfth, sulphurous smell."

Thus we see that every particular of lightning is identical with what has been observed of electricity.

Q. What results have other experiments on the atmosphere developed?

A. That the air is more or less charged, either positively or negatively, with electricity. It has been ascertained by experiments that the electricity of the atmosphere has a daily varying period,—like the ebb and flow of the tide,—its increase and decrease in power alternating in every twenty-four hours. In clear weather the electricity in the atmosphere is *positive;* in cloudy, damp, or stormy weather, it is *negative.* The electric intensity is least during the night, and greatest a few hours after sunrise.

The various kinds of lightning, such as the "forked," the "chain," the "sheet," and the "globular," may all be accounted for on the principles of electricity that have been mentioned.

Q. To what electrical phenomenon may the noise called thunder be primarily referred?

A. To the disruptive discharge, as exemplified in the explosion of the Leyden jar. The rolling sound of thunder is caused by the reverberating echo among clouds, or land.

Q. What other atmospheric phenomena may be dependent upon electricity?

A. Meteors, aurora borealis, waterspouts, and whirlwinds, and probably earthquakes.

Q. In summing up the subject, what principal physical effects may be derived directly from electricity?

A. From electricity, as an initiating force,

Motion in various forms is produced;

Heat is directly produced by it.

Light, of the greatest intensity, is another effect.

Magnetism is also peculiarly produced by electricity.

And lastly, *chemical affinity*, in certain metals and peculiar crystalline compounds, owes much to electrical agency.

Q. What have hitherto been the principal practical applications of electricity?

A. The *lightning conductor*, discovered by Franklin, and greatly improved by Sir W. S. Harris.

An *improved plan of blasting rock* on land or under water.

The *electric light*, for streets, signals, lighthouses, &c.

The *electrotype; electro-magnetic* machine for producing a *moving power;* and last, but not least, the *electric telegraph.*

Q. Having now considered most of the principles connected with heat, magnetism, and electricity, we may proceed to the more immediate consideration of chemistry itself, and may ask, at the outset, what are *elementary bodies*, or *substances?*

A. They are, as we have before said, *sixty-two* in number, and are called *elementary* because there is no process yet known by which they can be brought into a simpler form of matter; the analysis of these substances has been carried as far as present chemical knowledge can avail, and they have hitherto resisted all attempts to decompose them.

Q. As *elementary* substances have been divided by chemists into *metals* and *non-metallic*, it will be advisable to consider some of the *non-metallic* first. Beginning, therefore, with the components of the sea and the air, give some account of *oxygen.*

A. Oxygen exists in nature in a much greater degree than any other element. More than one half of the world and its inhabitants consist of oxygen. There would be no ordinary form of combustion without it; it exists very largely in the composition of the air, of water, rocks, and soils, and nearly all the productions of animal and vegetable life. Oxygen exists in an uncombined state in the atmosphere as a gas, mingled with

another gas, called *nitrogen.* All attempts to reduce it to a liquid or solid condition have hitherto failed.

Q. How is oxygen obtained?

A. From various substances, and in various ways; it is commonly obtained from the *black oxide of manganese.* This substance is composed, partly of a metal called manganese, and partly of oxygen. When subjected to furnace heat, the metal yields a fourth of its oxygen, or four parts out of sixteen, which the metal contains. A dark brown substance is left, containing twenty-seven parts of manganese, and twelve of oxygen; and this compound cannot be further separated by any degree of heat.

Another method of obtaining oxygen is from a substance called *chlorate of potassium,* or *chlorate of potash.* This salt is placed in a retort, and subjected to heat; at the boiling point it becomes decomposed, and yields a large quantity of oxygen gas, which may be collected in a jar or receiver, arranged for the purpose. The oxygen obtained from this process is the purest.

An easier method, as requiring a lower temperature, is to mix an equal part of black oxide of manganese in powder with the chlorate of potash, and then to subject it to a moderate heat in a retort. The object of the manganese is to facilitate the decomposition of the potassium, the manganese itself not undergoing any change. The oxygen thus obtained is not so pure as from the chlorate of potash alone. Indeed, that is the only source of *pure* oxygen.

Q. What are the *effects* of oxygen?

A. To cause bodies which burn in the air to burn with greater brilliancy in this gas; *ex. gr.* if a candle be blown out and presented to this gas while the wick remains red-hot, it will be immediately rekindled.

If a small piece of charcoal, lighted only at one point, be plunged into a jar of oxygen, it will burn with great brightness, and if the quantity of the oxygen be greater than the charcoal, the charcoal will be entirely consumed. Many other experiments may be made with oxygen,

tending to show that it supports combustion more readily and vividly than common air.

Q. What are *oxides?*

A. Compounds of oxygen with other bodies which do not possess *acid* qualities, are called *oxides.* They are chiefly compounds of oxygen with metals.

Q. Into how many classes are oxides divided?

A. Into *three* principal classes.

Q. What is the first class?

A. All the oxides which, in their chemical relations resemble potass, soda, or the oxide of silver or lead. All, in fact, which may be termed metallic.

Q. What is the second class?

A. Oxides which have properties opposed to those of the first class. Oil of vitriol and phosphoric acid are of this class, and are distinguished by the name of *acids.*

Q. What are the most remarkable properties of acids?

A. That they are soluble in water, that they have a sour taste, and that they change vegetable blues to red. When these acids tend to unite with the original oxides, they generate what is called a *salt.*

Q. How is the name of an acid in chemical language formed?

A. By adding the termination *ous* or *ic* to the name of the substance with which the oxygen is combined. Thus phosphorus forms *phosphoric acid;* carbon, *carbonic acid.*

Q. What are oxides of the third class?

A. Those which may be called *neutral* oxides.

Q. Why are they so called?

A. Because they do not readily combine with the oxygen. *Ex. gr.* the black oxide of manganese, which we have shown to yield oxygen but sparingly in one instance, and in the other only to facilitate the production of oxygen from the potassium.

Q. Sometimes a body unites with oxygen in such proportions that a series of oxides are formed; when this is the case, how are such oxides defined?

A. In the case of metallic oxides it is generally found that one out of the number has strong affinity for the original metal. In that case it is termed a *protoxide.* Those compounds which possess different degrees of affinity after this, are, in their order, called *binoxides, teroxides,* &c., from the Latin or Greek numerals.

Q. If there is a compound between the protoxide and binoxide, what term is given to it?

A. It is called a *sesquioxide.*

A compound with very little acid in it is called a *peroxide*; and a compound with less oxygen than the protoxide is called a *suboxide.*

Q. What is an *alkali?*

A. An alkali is a substance possessing the power of neutralising the effect of acids.

Q. What are the most powerful alkalies?

A. *Ammonia, potassa,* and *sodium* or *soda.*

Q. Give an instance of the effect of an *acid* neutralised by an *alkali.*

A. If a few drops of diluted sulphuric acid were poured into a glass of any *vegetable blue* liquid, the blue would at once be changed by the acid to red. If now a solution of ammonia or potass were poured into the red liquid the colour would be changed into a greenish-blue, and the liquid would no longer have an acid or sour taste.

Q. What is *ozone?*

A. It is a modification of oxygen, but its peculiar composition is yet unknown. All that has been ascertained about it is that it differs from oxygen in emitting a peculiar and metallic smell, that it has a bleaching property, it corrodes silver leaf, tinges blue, and also frees iodine from iodide of potassium. Ozone is generally discovered in the atmosphere when electricity prevails. In fact, it seems to be generated by the electric spark acting on the dry oxygen of the air, and the peculiar metallic smell observable during a thunderstorm seems to be the result of the prevalence of ozone.

Q. What is a chemical *salt?*

A. When *acids* and *alkalies* are mixed in such proportions that they neutralise each other, a compound is formed called a *salt.*

Q. How is this discovered?

A. By subjecting the acid and alkali solution to evaporation, a number of transparent crystals will separate from it, and form the new substance, or salt.

Q. Name some of these salts.

A. *Sulphate of sodium, sulphate of potassium,* of *zinc, iron, copper,* &c.

Q. How are the salts *named* and *classed?*

A. According to the *acid* which they contain. When the name of the acid ends in *ic*, that of the salt ends in *ate*; and when the name of the acid ends in *ous*, that of the salt ends in *ite.*

Any substance which combines with the acid to form the salt is termed the *base* of the salt. Thus sulphuric acid, combined with ammonia as base, forms sulph*ate* of ammonia; sulphur*ous* acid, sulph*ite* of ammonia, &c.

Q. What is *hydrogen?*

A. It is a colourless and inflammable gas, and when quite pure is free from all smell. It is the lightest of all ponderable bodies, and yet oftentimes displays the heavy properties of a metal. Hydrogen and oxygen in combination form water; and hence its name, derived from the Greek words ὑδωρ, water, and γενναω, I generate.

Q. How is hydrogen generated?

A. *Water* is the source from which hydrogen is always obtained. The most convenient method of preparing it is by the action of zinc on sulphuric acid diluted in water.

To prepare this gas take a wide-necked bottle, to the mouth of which a stopper is closely fixed, having two holes in it for the insertion through one of a small tube funnel reaching nearly to the bottom of the bottle; and through the other of a bent glass tube to carry away the generated gas. Put some granulated zinc into the bottle with a little water, and then pour sulphuric acid slowly through the funnel into the liquid. Care must be taken

to allow a considerable quantity of the first generated gas to escape before collecting that which is required for use. What is required to be preserved may be collected in a receiver, in the same manner as oxygen. There are other methods of preparing *hydrogen*, but for all practical purposes, the one above stated is sufficient.

Q. What are the peculiar properties of *hydrogen?*

A. It has an explosive quality when mixed with atmospheric air. It is inflammable, but burns with a weak and pale light that cannot be sustained for any length of time. This gas has no power alone to sustain life; nor can it burn except when in contact with the air or with oxygen.

Q. What results are obtained by a proportionate mixture of *oxygen* and *hydrogen?*

A. *Intense heat*, and *brilliant light.*

By the *oxy-hydrogen* blowpipe, platinum, which resists the action of a smelting furnace, can easily be melted. And by the mixture of chalk powder with the flame of hydrogen, or by directing the flame upon a piece of solid quick-lime, a most brilliant light is obtained, which, by certain arrangements of reflectors, may be rendered visible at a very great distance.

Q. What are the essential conditions for obtaining *the greatest intensity of heat* from any substance?

A. That the bodies which combine to give out heat be mixed in the proper proportions; and that everything which would absorb heat, without contributing to its production, should be removed.

Q. What are the conditions for obtaining the *strongest light?*

A. That a solid substance be present in the flame, and raised to a very high temperature. It has been found that at a given temperature *solids* give out more heat than *gases.*

Q. How many known *oxides of hydrogen* are there?

A. Two, viz. *water*, and a peculiar substance called *binoxide of hydrogen.*

Q. By what two methods may the composition of *water* be determined?

A. By *analysis*, or separation, and *synthesis*, or putting together.

Q. How is the composition of water determined by analysis?

A. When acid is diluted in water, so as to render it a conductor, and a portion of it interposed between two plates of platinum connected with the poles of a galvanic battery, the liquid becomes decomposed; *pure oxygen* is derived from the water in contact with the plate belonging to the copper end of the battery; and *pure hydrogen* is obtained on the side of the plate connected with the zinc extremity. The *hydrogen* will be found double the volume of the *oxygen* if this experiment be long continued.

Q. Can water be decomposed in any other way?

A. Yes; by *heat.*

If a current of steam be passed through a heated iron tube which is partly filled with iron filings, and thence by a bent pipe through a pneumatic trough into a glass receiver, it will be found that the steam is decomposed; the oxygen continues with the iron, and the hydrogen is set free.

Q. How is the decomposition of water shown by *synthesis?*

A. The two gases are mixed together in the proportion of eight parts of oxygen to one of hydrogen, in a strong glass tube; two wires nearly meeting each other are placed at the top of this tube, and by their means an electric spark is passed through the gases, their ignition is thus effected, they combine, and water is formed.

Q. What proportions of hydrogen and oxygen have thus been ascertained to compose water?

A. Eight parts of oxygen to one of hydrogen, *by weight;* and one volume of oxygen to two volumes of hydrogen, *by measure.*

Q. What is *binoxide of hydrogen*, or *oxygenated water?*

A. By a complicated chemical process a certain pre-

paration of *oxygen*, instead of disappearing as a gas, is made to unite with water, and thus becomes *binoxide* of *hydrogen*. It is a colourless and transparent liquid, free from smell, has a sharp taste, blisters the skin, and bleaches vegetable colours. The least elevation of temperature decomposes it, and reduces it to the condition of common water.

Q. What is *nitrogen*?

A. Nitrogen, sometimes called *azote*, from *α*, primitive, and ζωή, life, is a colourless gas, free from smell, and incapable of being rendered either liquid or solid.

Q. What are its peculiar characteristics?

A. It extinguishes flame; does not burn in the air; has no effect, when pure, upon colour; and has no power to support animal life, though it forms an important constituent of the animal body, and also enters into the structure of plants.

Q. How is *nitrogen* procured?

A. The most simple method is to destroy the oxygen in some confined space, such as a glass jar, by means of a piece of lighted phosphorus. When the oxygen is consumed the water around the jar rises and occupies the place of the oxygen, or $\frac{1}{5}$ of the bulk of the air in the vessel. The remainder, therefore, or $\frac{4}{5}$ of the air, is *nitrogen*.

Q. What is the chief use of nitrogen in the air?

A. To dilute the oxygen, and thus to prevent the too rapid action of combustion.

Q. What gases compose the atmosphere?

A. *Oxygen*, *nitrogen*, and a small portion of *carbonic acid* gas; also some portion of *watery vapour*, and a small proportion of *ammonia*.

Q. What remarkable property of oxygen and nitrogen is discoverable in the air?

A. That the oxygen and nitrogen are in a state of *mixture*, and that they always bear a uniform ratio to each other. The quantity of carbonic acid, however, is subject to variation from local causes. If it were not for

this uniform distribution of the two principal gases, the atmosphere would be arranged in separate strata: the nitrogen, from its lightness, above; the oxygen below.

Q. What brief, but important facts should be remembered as to the gases mentioned?

A. That carbonic acid gas puts out flame, and does not take fire.

That *hydrogen* burns, but does not maintain flame.

That *oxygen* supports flame and also animal life.

That *nitrogen* does not support flame, nor does it take fire.

Q. What are the *compounds* of nitrogen and oxygen?

A. There are five chemical compounds of these two gases, *viz.*: —

Nitrous oxide, or *protoxide of nitrogen.*

Nitric oxide, or *binoxide of nitrogen.*

Nitrous acid.

Hyponitric acid.

And *nitric acid.*

These substances are symbolically expressed in the following terms, according to their order above: —

$$NO$$
$$NO^2$$
$$NO^3$$
$$NO^4$$
$$NO^5$$

Q. What is *nitric acid?*

A. A compound of *nitrogen* and *oxygen.* It is obtained from *nitre*, or *nitrate of potassa.* This is found in hot and dry climates, where rain is scarce; it may be collected from the surface of the ground where it appears in saline particles. If this substance is dissolved in hot water, and the solution filtered and crystallised, it appears as *nitre*, or *saltpetre.* This and oil of vitriol put into a retort and heated, give out *nitric acid. Nitric acid* and *ammonia* supply plants with *nitrogen.*

Q. Before entering upon the subject of chemical symbols, however, it will be well to consider several sub-

stances and compounds without reference to symbolical nomenclature.

Explain, therefore, the nature of *ammonia* or *hartshorn.*

A. It is a gaseous substance composed of hydrogen and nitrogen. It is sometimes called *volatile alkali.* It can be made by heating a mixture of one part of powdered *sal ammoniac* and two parts of *quicklime* in a retort; the result is a gas called *ammonia.*

Water absorbs a great quantity of this gas, and the solution is called *liquid ammonia.* This substance is also abundantly produced from animal and vegetable matter in a state of putrefaction. The gas thus formed rises into the air, and from its readiness to mix with water it is washed down by the rain to enrich the soil.

Q. Why is it that animal bodies yield ammonia freely?

A. Because ammonia results from the union of hydrogen and nitrogen, the latter of which abounds in animal bodies; hence it is that *animal* bodies yield so much more of ammonia than *vegetable,* which give off *oxygen,* and but a very little, if any, *nitrogen.*

Q. What compound of ammonia is found in rain-water, and why?

A. *Nitrate of ammonia;* which is owing probably to the agency of electricity in the atmosphere.

Q. What is *chlorine?*

A. It is a gas deriving its name from χλωρος, or yellowish-green, because it is of that colour. Though generally obtained as a gas, it can also be reduced to a liquid by pressure at a common temperature.

Q. From what source is chlorine generally derived?

A. From *common salt,* called *chloride of sodium.*

Q. How is it prepared?

A. By distilling a mixture of *peroxide of manganese, common salt,* and *oil of vitriol;* or a mixture of *peroxide of manganese* and *hydrochloric acid.*

In the latter case, when a gentle heat is applied, both substances are decomposed; the hydrogen of the acid absorbing all the oxygen contained in the manganese, to

form water; while the manganese combines with half the chlorine, and the other half is liberated in the form of gas. It is a dangerous gas to prepare, as it strongly affects the respiratory organs.

Q. What are the principal uses of *chlorine?*

A. It is used chiefly as a bleaching agent, and also as a purifier of a tainted atmosphere. All vegetable colours are destroyed by chlorine when mixed with a certain quantity of water; and all poisonous exhalations from animal and vegetable substances in a state of decomposition are destroyed by it, as, also, all infectious matter of fevers and other diseases.

Q. What are its combinations?

A. With certain metals it combines to form *chlorides.* Most metallic oxides dissolve in it. With *hydrogen* it forms *hydrochloric acid,* which again being mixed with *nitric* acid, forms *aqua regia,*—an acid capable of dissolving gold.

With mercury it forms two chlorides; one containing 100 parts of mercury, forms *calomel;* the other containing 200 parts, forms *corrosive sublimate.*

With *oxygen* chloride combines to form five *acids;* viz. *hyperchlorous acid, chlorous acid, hyperchloric acid, chloric acid,* and *perchloric acid.*

Q. What is *hyperchlorous acid?*

A. It is a gas of a deep yellow colour, having a smell like chlorine, but not so powerful.

It has a powerful bleaching property.

With alkalies it forms a series of bleaching salts, called *hypochlorites.* The most useful of this class of salts is the bleaching powder commonly called *chloride of lime.*

Q. Describe *chlorous acid?*

A. It is a greenish-yellow gas, not easily soluble in water; it produces a class of salts called *chlorites.*

Q. What is *hypochloric acid?*

A deep yellow-coloured gas, very explosive, and consequently dangerous, for experimenting. The safest method of obtaining it is to decompose a few fragments of

chlorate of potash in a test tube, by adding to them a few drops of oil of vitriol.

Q. What are the composition and properties of *chloric acid?*

A. This acid is prepared from *chlorate of baryta*, to which *sulphuric acid* is added. If carefully evaporated, the acid may be so concentrated as to assume the consistence of a syrup. It is then very easily decomposed, and the results of such a process are *chlorine*, *oxygen*, and *perchloric acid.*

The chief properties of chloric acid and its chlorates are the facility with which they give out oxygen, and their affinity for combustion. *Chloric acid*, combined with *potassa*, forms *chlorate of potassa*, a salt which, when mixed with *sulphur*, is used in the composition of lucifer matches.

Q. What is *perchloric acid?*

A. The name of this acid is intended to denote that it contains more oxygen than the chloric acid. It is a colourless solution, and when strong, smokes slightly in the air. It is the most stable of all the compounds of chlorine and oxygen.

Q. What is *sulphur?*

A. It is an elementary substance of considerable importance, and differs from the substances hitherto considered inasmuch as it is found *alone* in the *native* state, as well as in combination with various metals; while the other substances are never found in a separate condition.

Q. In what form is native sulphur sometimes found?

A. In Sicily, and some other volcanic countries, pure sulphur is found in the form of well-defined octohedral crystals.

It is more frequently, however, found mixed with *iron* and some other metals; also with *clay*, *limestone*, and *gypsum.*

Q. Is sulphur obtained from any other source?

A. Yes, from the binary compounds of sulphur with some metallic body, such as iron. This compound is called *bisulphide of iron*, or *iron pyrites.*

When heated, this substance gives off half its sulphur in the form of vapour.

Q. What is *crude sulphur*, and how is it obtained?

A. It is called *crude* when freed from earthy and other matters, and it is obtained by heating in an iron vessel till the sulphur melts; the impure and earthy particles then sink to the bottom, and the pure sulphur is poured out into moulds ready for use.

Q. Is sulphur found in any other state?

A. Yes, it enters into the composition of many *vegetables*, probably also into *animal fluids*.

Q. Prove this.

A. The presence of sulphur in mustard, for instance, is proved by the discolouring of a silver spoon when allowed to remain in the mustard-pot. Still more rapidly does a silver spoon blacken if plunged into a boiled egg.

Q. What is the product called *flowers of sulphur?*

A. When *crude* sulphur undergoes a still further process of purifying, it is strongly heated in an iron vessel, and the vapour arising from it is collected in a large stone chamber, on the sides of which it condenses. While this chamber is below the temperature at which sulphur melts, viz. 234°, the vapour condenses on the walls in small crystalline grains of a light yellow colour — this condition is called *flowers of sulphur.*

As soon as the temperature rises above the melting point, the vapour condenses in the form of liquid sulphur, which is drawn off from the chamber and run into moulds. It is then called *rolled* sulphur, or *brimstone.*

Q. Can sulphur be obtained in any other way?

A. In that of regular crystals.

Q. By what process?

A. By dissolving it in *oil of turpentime*, or in *sulphide of carbon.*

Q. Can sulphur be converted into a *gas*, and at what *temperature?*

A. At 788° F. sulphur boils, and if retained in a close vessel it is converted into an orange coloured gas.

Q. What are the principal manufacturing processes in which sulphur forms an important element?

A. The manufacture of *gunpowder* and of *oil of vitriol.*

Q. What are the principal *compounds* of *sulphur* and *oxygen?*

A. *Sulphurous acid,*
Sulphuric acid,
Hyposulphurous acid,
Hyposulphuric acid,
Sulphuretted hyposulphuric acid,
Bisulphuretted ditto,
Trisulphuretted ditto.

Q. How is *sulphurous acid* prepared?

A. By heating oil of vitriol with metallic mercury; a portion of the acid is then decomposed, one-third of the oxygen is transferred to the metal, and the sulphuric acid becomes *sulphurous.*

This acid assumes the condition of a *gas,* but it can be condensed into a *fluid,* and, by extreme cold, may be rendered *solid.*

It has the power of bleaching.

Q. What are the properties of *sulphuric acid?*

A. This acid is rarely found uncombined with another substance. It has such a tendency to unite with water, that it can only exist in vessels that have been freed from every drop of moisture.

The strongest *oil of vitriol* is a compound of one part of real sulphuric acid, with one part of water.

Q. What are the components of *hydrosulphurous acid?*

A. Sulphur and a solution of sulphite of potassa being boiled together, the sulphur requisite to form a hyposulphite enters into combination; and when this solution is filtered and evaporated, pure hyposulphite results.

Q. What remarkable feature may be observed in the alkaline hyposulphites?

A. That they possess the property of dissolving the otherwise insoluble salts of silver.

Hyposulphite of soda is now manufactured in considerable quantities for photographic purposes.

The other three compounds of sulphur and oxygen which have been named, need not be described, as they are but of little importance.

Q. What are the compounds of *sulphur* and *hydrogen?*

A. They are two; viz. *hydrosulphuric acid,* or *sulphuretted hydrogen,* and *bisulphuretted hydrogen.*

Q. What are the properties of *hydrosulphuric acid?*

A. It is a colourless gas of a very disagreeable smell, like that of rotten eggs. It is found in a state of solution in some mineral waters, called *hepatic waters,* such as the spring at Harrogate. When undiluted, this gas is of a very poisonous nature, and is one of the chief causes of noxious exhalations from sewers.

Q. What effect has *chlorine* upon this acid?

A. It decomposes it entirely, and, therefore, destroys its poisonous properties.

Q. Of what *chemical* use is hydrosulphuric acid?

A. Both as a gas and in solution it decomposes a great number of metallic compounds, oxides, &c. It will detect the minutest traces of many metals in any compound, while the solutions of many of the metals themselves indicate the presence of the gas. Hence, in chemical analysis, this gas is of great use.

Bisulphuretted hydrogen, the other compound of sulphur and hydrogen, is of little importance, and need not be further mentioned here.

Q. What is *selenium,* and where is it found?

A. It is a solid body, of a reddish brown hue, insoluble in water, and of a disagreeable smell. It is one of the rarer elements, and is found in combination with sulphur, which it resembles in some respects; it is also found combined with lead, copper, and some other metals, but more commonly with sulphur, in the Lipari Islands.

Q. In what points does it resemble sulphur?

A. That it is found in the three conditions of solid, liquid, and gaseous. That it forms *selenious* and *selenic* acids; and also that it crystallises like sulphur.

Q. What is *bromine?*

A. At ordinary temperatures, bromine is a red and thick liquid, slightly soluble in water, and most freely in ether. The chief source of bromine is sea-water, and in certain springs, particularly that of Theodorshall, near Kreuznach, in Prussia. It has the property of decomposing several organic compounds, and of bleaching vegetable colours.

Q. What are its compounds?
A. *Hydrobromic acid*, and *bromic acid.*

Q. How is *iodine* obtained?
A. Principally from kelp, or the half-vitrefied ashes of marine plants. This substance is a solid of a darkish blue colour. It is probable that marine plants absorb nearly all the iodine from salt water, as but few traces of it are found, except in the plants themselves.

Iodine is prepared principally in Glasgow, from the kelp collected on the Irish and Scotch coasts.

Q. In what combination is iodine used?
A. As a medicine, when dissolved in alcohol; and sometimes as a compound of *iodide of potassium*, an efficacious remedy for glandular swellings.

Q. What are its compounds?
A. *Hydriodic acid gas*, *iodic acid*, and *periodic acid.*

There are also *metallic iodides;* compounds closely resembling chlorides and bromines. The silver plates used in the daguerreotype process are prepared by exposing the plate to the action of *iodine vapour*, which suffuses the plate with a silvery film very sensitive to light.

Q. What are the properties of *fluorine?*
A. It is presumed to be of a gaseous nature, but as it has never been sufficiently separated from other matters for examination, its properties are not clearly defined. It is derived from *fluor spar*, found in parts of England; on the application of *sulphuric acid* to this spar, *hydrofluoric acid* results, and it is in this combination that fluorine is principally used.

One distinguishing quality of this substance is its

tendency to combine with other elements, so that if separated from one, it immediately mingles with another.

Q. What is the principal use of hydrofluoric acid?

A. It is employed in the process of etching upon glass.

Q. How is this performed?

A. The glass is thinly coated with wax, upon which the pattern to be engraved is drawn, so that the lines appear, through the wax, on the glass. The diluted acid is then poured upon these lines, where it corrodes, and upon the removal, after a time, of the wax, the pattern will be found engraven on the glass.

Great care is necessary in the use of this acid, as it is of a very dangerous nature.

Q. What is *silicium* or *silicon?*

A. In combination with oxygen, it constitutes *silica*, or the earth of flints, which is one of the most common substances in nature. From this common substance, however, in different forms, are derived *rock-crystal*, *quartz*, *amethyst*, *jasper*, *opal*, *chalcedony*, *onyx*, *cornelian*, *agate*, and *bloodstone*, besides *flint* and *sandstone*.

Chemically treated, silica is found to be an *acid*, insoluble in water; when heated with gases which are capable of undergoing fusion, it unites with them, and forms salts, which are sometimes soluble in water.

Q. In what manufactures is silica employed?

A. In those of glass and porcelain.

Q. What other substance is nearly related to silicium?

A. *Boron;* which is not a very abundant element, and which is principally used in combination with oxygen to produce *boracic acid.* This acid is manufactured in Tuscany, where it is found in solution with the water of several volcanic marshes.

It is also procured from *borax*, a salt found in some lakes of Thibet, and mixed with sulphuric acid.

Q. Describe *phosphorus.*

A. Phosphorus differs from the substances we have been considering, inasmuch as it is derived, not so much from the *mineral*, as from *animal* nature, the chief source

of its preparation being *bones* and *animal fluids.* It is also found in some *vegetable* matter.

Q. In what conditions may phosphorus be obtained?
A. In *three,* viz. *solid, liquid,* and *gas.*

Q. What is the process generally adopted for obtaining phosphorus?
A. Bones are the principal source from which phosphorus is obtained; when burned, their animal matter is consumed, and a white friable mass is left, which consists of phosphate of lime. This substance being pulverised and mixed with an equal weight of oil of vitriol and 16 parts of water, decomposition follows. *Sulphate of calcium* remains, and *phosphoric acid,* which dissolves in the water. The liquid is now evaporated to the thickness of a syrup, and mixed with a sufficient quantity of powdered charcoal to form a kneadable mass, which is heated to redness and then allowed to cool. It is then put into a retort and gradually heated. As the heat increases, the charcoal decomposes the phosphoric acid, and combines with the oxygen to form carbonic oxide, which escapes as gas. The phosphorus passes off as vapour, and is received in a bottle partly filled with water. Coming in contact with the water the vapour becomes liquid, and being heavier than water, falls to the bottom, where the phosphorus is collected.

Q. From what other source may phosphorus be obtained?
A. From *urine,* in which it exists as phosphate of sodium, and phosphate of ammonium. This process is, however, now superseded by the extraction of phosphorus from bones, as just mentioned.

Q. How do you account for the luminous appearance of phosphorus in the dark?
A. By the fact that when exposed to the air it absorbs oxygen to such a degree, that slow combustion ensues, and this burning appears as a faint light in the dark.

Even slight friction will produce the same result on the phosphorus.

Q. How are the lucifer matches of trade generally made?

A. They are dipped in a mixture of *phosphorus* and *chlorite of potassium* for those which ignite with a noise; those which ignite silently contain nitre, as well as the above ingredients.

The paste in which the matches are dipped is made by melting phosphorus in water, then adding the chlorite of potassium, or the nitre, mixing all with a gum to form a paste.

The points of the matches are first dipped in sulphur, then into the above mixture, and then carefully dried.

Q. What compounds does phosphorus form with *oxygen?*

A. It forms *four* compounds, of which phosphoric acid is the most important.

Q. Name these compounds.

A. *Oxide of phosphorus; phosphorous acid; hypophosphorous acid;* and *phosphoric acid.*

Q. What is *oxide of phosphorus?*

A. By the combustion of *oxygen* with *phosphorus,* the latter is converted into a brick-red powder.

Q. How is *phosphorous acid* formed?

A. Commonly by placing sticks of phosphorus in a vessel of water, and supplying a current of air to the vessel. Any process for the slow combustion of phosphorus in the atmosphere is equally effectual.

Q. What is the principal feature of *hypophosphorous acid?*

A. Its tendency to unite with oxygen; and when brought into contact with the oxides of some metals, the oxygen is removed, the metal is reduced, and the hypophosphorous acid is changed to phosphoric acid.

Q. What is *phosphoric acid?*

A. It is the most important of all the compounds. It is produced by the rapid combustion of phosphorus in the air or in oxygen gas.

Q. How may it be easily obtained?

A. By setting fire to a piece of phosphorus on a plate, and then covering it with a large glass jar.

As the phosphorus burns, the acid will collect in snowy white flakes on the plate and on the sides of the vessel.

This acid has a very powerful attraction for water, so that it will even draw off the water from strong oil of vitriol.

Phosphoric acid is used for drying gases.

This acid is remarkable for the many modifications to which it can be subjected. It is found in every *bony* substance, and as animals derive their nourishment chiefly from the vegetable world, this compound must also exist in plants. Phosphoric acid must, therefore, either be found in or put upon the soil before it can be considered fertile.

Q. What is *carbon?*

A. It is one of the most important of chemical elements.

Q. In how many, and what forms does this substance occur?

A. In two distinct forms; viz: in the pure and crystallised condition, as the *diamond*; and in that of *black-lead*, or *graphite*, or, as it is sometimes called, *plumbago*.

Q. Does *carbon* occur in any other pure form?

A. Yes; In that of *anthracite*, or *Welsh stone coal.* In this mineral the carbon is really pure; it burns without flame, and requires a strong draught.

Q. Name some of the substances of common use in which carbon abounds.

A. *Charcoal, coke, lamp black, animal charcoal from bones.*

Q. How is charcoal prepared?

A. By the slow combustion of wood in some covered receptacle, so that little or no air can reach it to burn it away. This charcoal is impure *carbon*; the oxygen and hydrogen in the wood have been expelled by the heat, together with a certain portion of the wood by combustion, and what remains is termed charcoal.

Q. What properties does charcoal possess besides its utility for fuel?

A. When made from close-grained and heavy woods, it has the power of condensing gases and vapours into its pores; certain kinds of charcoal have the property of removing vegetable and animal colours; when prepared at a high temperature, it is a good conducting power for electricity; willow, and some other light woods, yield a very porous charcoal, which has the property of absorbing noxious vapours and bad smells, and also of filtering turbid and impure fluids.

Q. How is *coke* produced?

A. Coke, which is the charcoal of pit coal, is a more impure carbon than that derived from wood, though the proportion of carbon in it is greater than in wood. Sulphur and earthy matters enter largely into its composition. In the preparation of coke a large quantity of *carburetted hydrogen gas* is given out, and also a liquid known as *coal tar.* This gas is commonly used for lighting towns, and the coal tar for farming and other purposes.

Q. What is the composition of *lamp-black?*

A. It consists of *carbon* and *hydrogen,* and though the very opposite in appearance to the diamond, is, nevertheless, nearly the same as to its chemical nature.

It is prepared by the imperfect combustion of highly carbonised bodies, such as resin or pitch. These substances are burnt in a receptacle where the supply of the air to the vapour arising from them and set on fire is so regulated that much of the vapour settles as soot or lamp black on the inside of the chamber, and is there collected for use.

To free it from the oily matter connected with it, lamp black is afterwards calcined in a covered crucible.

Q. What is *animal charcoal?*

A. It is derived from bones which have been burnt in a covered crucible, or vessel from which the air is excluded. If the air were admitted the bones would consume and leave a *white ash;* when the air is excluded the gelatine in the bones is not evaporated but absorbed

into the substance, and the carbon remains mixed with the earthy matter in a black and porous mass. This reduced to powder is called *ivory black*, which, after being subjected to the action of hydrochloric acid, and washing, is fit for use.

Q. What compounds does *carbon* form with *oxygen?*

A. Two; viz. *carbonic oxide*, and *carbonic acid.*

Carbonic oxide, the less important of the two, is derived from the preparation of carbonic acid over red-hot charcoal; this process frees the acid from a portion of its oxygen, and it is converted into *carbonic oxide.*

There are several other methods of preparation, but this will suffice to explain the nature of the oxide.

It is a combustible gas, burning with a beautiful pale flame, but very poisonous.

Q. What is *carbonic acid?*

A. It is the compound always formed when carbon of any kind is burned in the air or in oxygen gas. Carbonic acid is a heavy gas which extinguishes flame, and destroys animal life.

Q. How is it obtained?

A. In several ways; but for the purpose of experiment the best method of obtaining it is to decompose a carbonate by mixture with some acid, such as sulphuric or hydrochloric acid. This gas is tasteless, has an agreeable odour, but is fatal to life.

Q. In what manner is it commonly found to be injurious to animal life?

A. It is so, because not a fire or a furnace is kindled without an abundant exhalation of carbonic acid; it is also produced by the fermentation of rotten animal and vegetable matter; and hence, when ventilation is bad or imperfect, when open cesspools or manure-heaps are close to the house, or when individuals are closely crowded in small and ill-ventilated rooms, great danger arises to human life, and fatal effects too often follow.

Q. While this acid is so injurious to animal life, what effect does it produce upon the vegetable world?

A. To plants it is of the greatest importance. They absorb it from the air, live upon it, and finally give it off from their leaves, in the sunshine, retaining the carbon and dispersing the oxygen. This can only be done in sunshine or light.

Q. Is carbonic acid found in minerals?
A. Yes; in great quantities, in the form of carbonates, chiefly carbonates of lime. The poisonous quality of the air in the *Grotto del Cane* at Naples, and in the *Poison Valley of Java,* may be attributed to the presence of carbonic acid in excess in those localities.

Q. How are *carbonates* freed from *carbonic acid?*
A. By decomposing them at a red heat. The common process of lime-burning consists in subjecting chalk, or any other kind of limestone to a red heat; the carbonic acid is then driven out, and lime is left.

Q. Name some of the most important compounds of *carbon* and *hydrogen.*
A. *Light carburetted hydrogen,* also called *marsh gas,* or *fire damp; olefiant gas;* and *coal* and *oil gases.*

Q. Why are these compounds important?
A. Because they illustrate the subjects of combustion, and the nature of flame.

Q. Where is carburetted hydrogen found?
A. In coal mines, particularly in apertures called "blowers," from whence a stream of this gas is often emitted.
Carburetted hydrogen is also found in the mud of stagnant pools.

Q. How can this gas be artificially procured?
A. From a mixture of 40 parts of acetate of soda, 40 parts of hydrate of potassa, and 60 parts of powdered quick-lime. This mixture being heated in a retort, gives out the gas in large quantities.

Q. What are the properties of *olefiant gas?*
A. This gas is produced by artificial means. It is colourless, neutral, and may be dissolved in water. Its

odour is like that of garlic; it takes fire easily, and burns with a brilliant white light.

Q. Why is it called *olefiant* gas?

A. Because when chlorine is mixed with it in certain proportions, the mixture gives forth a heavy oily liquid, sweet to the taste, and smelling of ether. This mixture is called *chloride of hydrocarbon*, and it is from the part which this gas takes in the compound that it is called *olefiant.*

Q. How is *coal* gas prepared?

A. The pit-coal from which it is obtained is put into large cast-iron vessels which act as retorts. These vessels are subjected to red heat, and the gas extracted from the coal is passed through a process of pipes in which the tar and liquid ammonia are condensed, and the gas itself freed from the sulphuretted hydrogen and carbonic acid which it before contained.

The *coal-gas* thus obtained is preserved in large cylindrical receivers immersed in tanks of water, and so arranged that the gas can be conducted through pipes to any required locality.

Q. What substances are separated from the coal-gas during the process of condensation and purifying?

A. Tar, and volatile oils; sulphate of ammonia; sulphuretted hydrogen; and carbonic acid.

Oil-gas can be made by the simple process of dropping oil into a red hot retort filled with coke. The cost of the oil, and the large quantity required, have prevented the manufacture of this gas for practical purposes.

Q. In considering the subject of *combustion*, when is a body said to be *incandescent*, or *ignited?*

A. When it is subjected to such a degree of heat as to emit light. Various degrees of heat produce various kinds of light, from a glowing red to a bright white or violet tint.

Q. What is the difference between *ignition* and *combustion?*

A. A body is said to be in a state of *ignition* when all the particles composing it are heated to redness; it is said to be in a state of *combustion* when, like charcoal, it retains its heat and glow after the fire that ignited it has been removed, and when, under the influence of its heat, it gradually wastes away.

Q. What is the ordinary process of combustion?
A. Its action takes place between the burning body and the oxygen of the air.

Q. What materials are commonly employed to produce heat and light?
A. Those which consist chiefly of *carbon*, or of a combination of it with hydrogen and oxygen.

Q. What method is employed to increase the heat of ordinary fires?
A. By the introduction of a greater quantity of air, and in a more rapid manner than usual in ordinary fires, the intensity of the heat becomes much greater, the temperature being raised in a definite proportion to the amount of chemical action employed.

Q. How is this principle applied for practical purposes?
A. Either by the bellows—as in the blacksmith's forge—and the blowpipe; or in the construction of chimneys in such a manner that a powerful current of air should be rapidly drawn through the fire from which it can have no outlet but through their channel.

Q. It has been said that solids and melted metals, when sufficiently heated, emit *light;* when do bodies also emit *flame?*
A. When their temperature has been raised considerably higher than that required for *light.* Gas or vapour at their elevated temperature constitutes *flame.*

Q. Upon what does the illuminating power in flame principally depend for its brightness?
A. Upon the presence of some solid matter under the influence of ignition; as, for instance, a piece of lime under the action of the hydro-oxygen blowpipe.

Q. What is the structure of the flame in a lamp or candle?

A. It consists of *three* separate portions; the dark part in the centre consists of matter drawn up by capillary attraction through the wick, and evaporated by the heat; next to this appears a bright cone of light, from which soot falls if brought into contact with any cold body; outside this another cone of a pale colour is seen, this gives out little light, but great heat.

Q. On what principle can this regular structure of flame be explained?

A. Upon the pale or outer cone of flame the oxygen of the air prevails to excite combustion; within this cone oxygen is present in a much less quantity, while hydrogen and carbon are contending to absorb it, the former consuming more than the latter. This process creates a deposit of particles, which, becoming intensely ignited by the burning hydrogen, give out a white and brilliant light: the heat of this cone draws off or volatilises the matter from the inner cone and wick, and thus the flame is fed and supported.

Q. Before we proceed to the consideration of some of the metallic compounds, it will be necessary to ask a few questions upon what may be termed the laws and language of chemistry. What, then, are the laws which regulate chemical combinations?

A. They are *four*, viz.: —

1st. That all chemical compounds are definite in their nature, combining in definite quantities or proportions by weight: thus, water consists of eight parts of oxygen and one part of hydrogen by weight; and this proportion is true of water in whatever quantity, or however generated.

Q. What is the *second* law?

A. That when a body unites with another body in several proportions, these proportions bear a similar relation to each other.

Q. What is the *third* law?

A. It is called the *law of equivalent quantities;* and is in effect the choice of some one elementary substance as the unit of a scale to which the equivalents of other elements are referred.

Thus, if hydrogen be taken as the base of the scale, and its equivalent be called one, then, measuring by this scale, the equivalents of others will be: oxygen equals 8 parts, carbon equals 6, nitrogen equals 14, sulphur equals 16, phosphorus equals 31, iron equals 28, chlorine equals 35, &c. These numbers not only show the proportions in which these bodies combine with hydrogen, but they also show the proportions in which they combine among themselves and form certain compounds; thus hydrogen and chlorine combine to form *hydrochloric acid* in the proportions of one to thirty-five.

Q. What are *chemical equivalents?*

A. The numbers representing the quantities of substances *equivalent* to each other, and capable of being substituted for one another in combination.

Q. What is the *fourth* general law?

A. That the combining quantity of a compound is the sum of the equivalents of its components. Thus the equivalent or combining quantity of carbonic oxide is 14, that number being the *sum* of 6 and 8, the combining numbers of its components.

Q. What is the law of combination by *measure* or *volume* among gases?

A. That quantities by weight which combine, occupy, under similar circumstances of pressure and temperature, either equal volumes or those which bear a simple proportion to each other, as one to two, one to three, &c.

Q. Name the elementary substances at present known, with their *symbols* and *equivalents* on the *hydrogen* scale.

A. Dividing these elements into classes according to certain characteristics possessed in common by each class, we have the following table, of which those printed in *italics* are rare and less important elements.

NAME.	Symbol.	Equivalent.
NON-METALLIC ELEMENTS.		
Oxygen	O	8
Hydrogen	H	1
Nitrogen	N	14
Carbon	C	6
Sulphur	S	16
Selenium	Se	40
Phosphorus	P	32
Chlorine	Cl	35·5
Bromine	Br	80
Iodine	I	126
Fluorine	F	18·7
Silicon	Si	21·5
Boron	B	10·9
METALS.		
CLASS I.		
Potassium	K	39
Sodium (Natronium)	Na	23
Lithium	Li	6·4
CLASS II.		
Barium	Ba	68·6
Strontium	Sr	44
Calcium	Ca	20
Magnesium	Mg	12·7
CLASS III.		
Aluminum	Al	13·7
Glucinum	G	26·5
Yttrium	Y	32·2
Erbium		
Terbium		
Zirconium	Zr	33·6
Thorium	Th	59·6
Cerium...	Ce	47·3
Lanthanum	Ln	47

Name.	Symbol.	Equivalent.
METALS—*continued.*		
Class IV.		
Didymium	Di	49·6
Manganese	Mn	27·7
Iron (Ferrum)	Fe	28
Chromium	Cr	28·2
Nickel	Ni	29·5
Cobalt	Co	29·5
Copper (Cuprum)	Cu	32
Zinc	Zn	32·5
Cadmium	Cd	56
Bismuth	Bi	213
Lead (*Plumbum*)	Pb	104
Class V.		
Uranium	U	60
Vanadium	V	68·6
Tungsten (*Wolfram*)	W	95
Molybdenum	Mo	48
Columbium	Cm	184
Niobium		
Pelopium		
Titanium	Ti	24·5
Tin (*Stannum*)	Sn	59
Antimony (*Stibium*)	Sb	129
Class VI.		
Osmium	Os	99·6
Gold (*Aurum*)	Au	199
Mercury (*Hydrargyrum*) ...	Hg	100
Silver (*Argentum*)	Ag	108
Platinum	Pt	98·7
Palladium	Pd	53·3
Iridium	Ir	98·7
Ruthenium	Ru	52·1
Class VII.		
Rhodium	R	52·1
ELEMENTS OF INTERMEDIATE PROPERTIES.		
Arsenic	As	75
Tellurium	Te	64

Q. What may be called the *language* of chemistry?

A. The chemical name given to a substance which serves as an index of the proportion in which the elements of that substance are combined.

Q. Give instances of this chemical nomenclature.

A. Compounds which contain oxygen are called *acids* or *oxides;* those which contain chlorine are called *chlorides;* those which contain iodine are called *iodides*, &c.

A compound of one equivalent of a metal with one equivalent of the other element is called a *protoxide*, or *proto*-chloride, as the case may be, signifying that it is a *first* or *primary* compound.

So also compounds which contain one equivalent of a metal united with one and a half, two, three, four, and five equivalents of the other element, are called *sesqui*, *bi*, *ter*, *quadro*, and *quinto;* as, *sesqui*-oxide, *bi*-oxide, &c.

Q. By what term is the *highest* degree of oxidation usually expressed?

A. By the term *peroxide;* this term does not refer to the *proportions* in which the metal and the oxygen are united, but to the intimate or highest union of these elements.

Q. To what condition of a substance is the termination *ic* applied?

A. To its condition when it becomes an *acid.*

Q. When substances form *two* acids, what termination is appended to that which has the smaller proportion of oxygen?

A. The termination *ous.*

Q. What other termination is given to a compound?

A. That of *uret;* ex. gr. *sulphuret* of iron, &c.

Q. When an acid whose name ends in *ic* forms a salt, what ending is given to the name of the compound?

A. That of *ate;* ex. gr. *nitric* acid forms a *nitrate.*

Similarly, when an acid ends in *ous*, its salt ends in *ite.*

Q. For the sake of brevity, chemical formulæ are commonly expressed by *symbols;* what are they?

A. A system has been formed to represent the equivalent of each element by the initial letter of its Latin name in capital, or by the first letter joined with a small one, the most characteristic in the whole word. The single letter is generally used for the most important elements.

The symbol attached to the initial of a substance always represents its combining equivalent. Thus, hydrogen is represented by H, oxygen by O, and water by HO, or H+O.

These symbols not only stand for the name of the element itself, but they denote the *equivalent quantity* of that element: thus when H and O are mentioned they are invariably understood to bear the proportion to each other of one to eight, the relative proportion of hydrogen and oxygen.

Q. What symbol is used when a compound contains two or more equivalents of any of its elements?

A. A small figure is placed at the right hand of the symbol, and just below it; thus, if chlorine and oxygen were combined in the proportion of three equivalents of oxygen, the symbolical expression would stand thus:

$$ClO_3$$

Q. How is combination between two compound bodies expressed?

A. By the sign of *addition*, or by a *comma* between them.

Thus, sulphate of soda is expressed by the formula

$$NaO + SO_3 ; \text{ or } NaO, SO_3$$

By such a system chemical decompositions can be represented in the form of equations; the left hand side of the equation representing the elements before chemical action takes place, and the right hand side showing the change produced.

Q. How many metallic elements are at present known?

A. About *forty-seven;* but of these a great number are of rare occurrence, and many of them quite unknown in common use.

Q. What are the general properties of metals?

A. *Lustre, colour, specific gravity, brittleness, malleability, ductility, fusibility, tenacity,* and *volatility.*

Q. What is the metallic lustre?

A. A peculiar brightness thrown off from the surface of metals, differing greatly in power according to the metal employed.

The thinnest leaves of metal are so opaque that they entirely arrest the passage of light, but reflect it as a mirror.

The degree of lustre varies greatly; *manganese* being almost without any, while *gold* and *silver* possess a brilliant lustre.

Gold is less opaque than other metals; gold-leaf, when suspended in the light, showing a greenish and semi-transparent hue.

Q. What *colours* are generally observable in metals?

A. Copper is *red,* gold *yellow,* bismuth a feeble *pink,* and the rest vary from the pure *white* of silver to the *bluish-grey* of lead.

Q. Which metal is the heaviest, and which the lightest as to its *specific gravity?*

A. *Platinum* is the *heaviest* and *sodium* the *lightest* of all metals.

Q. What are the most *brittle* of the metals?

A. *Arsenic* and *antimony;* and *zinc* and *bismuth* to a certain degree, and under certain conditions.

Q. What metal is the most *malleable?*

A. *Gold* is the most so; next to it, *silver, copper,* and *tin;* and *iron, palladium, lead, nickel,* and some alkali metals, when rendered solid, are also malleable.

Q. What is the *ductility* of a metal?

A. It is a property of certain metals, somewhat allied to that of malleability, but differing from it as involving the principle of *tenacity.*

Gold and *platinum* are among the most ductile metals, one grain of the former having been drawn out to a length of 530 feet.

Q. How is the *tenacity* of metals ascertained?

A. By using wires of the same size but of different metals, and ascertaining how much weight they will sustain.

Q. What is the ascertained order of tenacity among the metals?

A. *Iron* is the most tenacious; next in order are *copper*, *platinum*, *silver*, *gold*, *zinc*, *tin*, and *lead*, which possesses this quality in the least degree.

Q. What is the quality of *fusibility?*

A. The power which a metal possesses of melting at a certain temperature. Probably all metals possess this quality. *Arsenic* alone, when subjected to a fusible heat, changes at once from a solid to a vapour, without assuming the liquid form of fusion.

Mercury is fusible at the low temperature of 39° Fahr. *Tin*, *lead*, and *potassium* at moderate temperatures; *gold*, *silver*, and *copper* are fusible at a heat just below redness. *Pure iron*, *nickel*, and a few other metals are fusible only in the intense heat of a wind furnace; while *platinum*, and some other metals of less importance can only be fused at all by the action of the oxy-hydrogen blowpipe.

Q. How are metals *volatilised?*

A. By the application of very great heat.

It is probable that all metals might be rendered volatile if a sufficient degree of heat could be applied to them. Mercury will boil and vaporise below a red heat, while others, such as gold, silver, and platinum, refuse this condition, even when exposed to the heat of a wind furnace.

Some metals, such as *platinum* and *iron*, assume a soft condition before melting, in which condition one piece can be welded or joined to another with perfect ease. An example of this may be seen in almost every operation of the blacksmith, and, on a larger scale, in the manufacture of anchors.

Q. Having briefly considered the common properties of all metals, it will be useful to consider a few of the

principal metals themselves in their chief individual features, and also in their relation to each other. Among the first class of metals, viz., those of the alkalies, give some account of *potassium*.

A. This is called one of the *fixed* alkalies, to distinguish it from the *volatile* alkali of ammonia. It is a brilliant white metal, of the colour of silver, soft at the common temperature of the air, but at 32° it becomes brittle and crystalline. It melts at a moderate temperature, and distils at a low heat. When thrown upon water, it takes fire instantly, burning with a purple flame.

This metal forms two compounds with oxygen, viz., *potassa* and *teroxide* of potassium.

Q. What is *potassa* or *potash?*

A. When heated in dry air, potassium burns, and is changed into a white volatile substance, which is called *potassa*.

Q. What are some of the uses of *potash?*

A. It is an intense alkali, saturating the most powerful acids, restoring the colours of vegetable blues that have been turned red, and changing many of them to green.

With various fats it combines to make soap. Solid potash is used as a caustic by surgeons. A solution of it absorbs carbonic acid ; and in its solid form it removes both carbonic acid and moisture from the air.

Q. What is *teroxide* of potash?

A. A fusible substance of an orange-yellow colour, generated by the burning of potassium in dry oxygen gas.

Q. What *salts* are derived from potash?

A. The most important are *carbonate of potash*. This is sometimes called *pearlash* and *potash*, and is an alkali obtained from the ashes of forest trees that have been subjected to a certain preparatory process.

Another important salt is called *bicarbonate of potash*.

Nitrate of potassa, *nitre*, or *saltpetre*, is an important compound, found in hot and dry soils in which animal matters decompose. It is also formed artificially, by

heaping together mortar, earth, and animal matter, and wetting the whole with fermenting urine.

The nitre used in England comes from the East Indies; it forms a principal ingredient in gunpowder, which is made by mixing together one equivalent of nitre, three equivalents of carbon, and one equivalent of sulphur.

Q. Give some account of *sodium.*

A. It is a metal very similar to potassium, and may be obtained by decomposing carbonate of soda by charcoal, at a high temperature.

Q. What are its principal salts?

A. *Common salt,* or *chloride of sodium.* It is formed by saturating carbonate of soda with hydrochloric acid, and then evaporating the mixture till crystals form.

In many parts salt is obtained by evaporating sea water; in other places from beds of rock salt.

Carbonate of soda is obtained from common salt. In its common form carbonate of soda is a dry powder, called *soda ash.* From it all other salts of soda are obtained by the addition of the proper acid.

Q. What are the principal uses of carbonate of soda?

A. It is extensively used in the manufacture of soap, and some kinds of glass.

Q. In the second class of metals, those of the alkaline earths, name the most important.

A. *Calcium,* and its compounds. Calcium is a yellowish-white metal, particularly ductile, and may be cut or hammered into thin plates.

Q. What is its most important oxide?

A. *Lime,* which forms large beds and mountain masses in all parts of the world, appearing as marble, limestone, chalk, and coral.

Lime is essentially necessary to all good soils, and its use is of great importance in agricultural chemistry.

Q. How is common lime prepared?

A. By heating limestone, or carbonate of lime, in large furnaces filled with limestone and fuel. The lime

as it is burnt and prepared, is drawn out from the bottom of the furnace, and replaced at the top by fresh limestone.

Q. What is its operation in *mortar?*

A. It acts as a cement by the slow formation of a carbonate of lime, which mixes with the grains of sand or ashes that make up the greater part of the mortar; the mixture hardens by its gradual absorption of carbonic acid from the air.

Q. What is *hydraulic lime?*

A. A certain preparation of limestone, in which oxide of iron, manganese, and silica are found. Lime prepared from such materials has the power of hardening under water.

Q. What are the principal compounds of lime?

A. *Sulphate of lime*, or *gypsum*, much used as a manure for sandy and barren soils.

Phosphates of lime, which are soluble in acids.

And *chloride of lime*, which is formed when chlorine gas is admitted to hydrate of lime rendered slightly moist.

Chloride of lime is employed in the arts as a bleaching powder, and is also useful for disinfecting purposes, particularly when mixed with a little acid.

Q. What are the properties of magnesium?

A. It is a white, malleable metal, fusing with a red heat, and burning with a brilliant light.

Q. What is its oxide?

A. *Calcined magnesia*, which is left when the carbonate of magnesia is heated to redness.

It is a white powder which attracts moisture and carbonic acid from the air; it neutralises acids, and is used in medicine as an aperient.

Q. What metal is the most important among those which have been mentioned in the third class?

A. *Aluminum*. As a metal it is difficult to obtain. When heated it burns with a bright light, and yields an oxide called *alumina*.

Q. What are the properties of *alumina*?

A. It is found in *ruby* and *sapphire; emery* is also nearly pure alumina. It enters into the composition of *felspar*, and some other minerals, from whose decomposition various clays are produced.

Pure alumina is a fine white powder. It is the basis of the art of pottery.

Q. What *salt* is the most useful among the compounds of *alumina*?

A. *Alum*, which is a double sulphate of alumina and potash. Alum is a soluble salt with an astringent taste, and crystallised in a regular system.

Q. What is the principal use of alum?

A. It is employed in the arts of dyeing and tanning, and also in the preparation of what is called *lake* in certain colours.

Q. What are the peculiarities of the metals contained in the fourth class?

A. The metals of this group are to be found in the pure state; they can easily be reduced from their compounds; and two of them are found in the earth in their metallic state. These metals are only found in mineral veins, traversing granite, slate, or limestone rocks.

Q. Give some account of the most important metal,—*iron*?

A. Metallic iron is rarely found; nor is it easily obtained in its pure state, as it is generally mixed with a portion of *silicon* and *carbon*. Iron, however, is the most abundant, as it is also the most useful known metal.

Its ores are found everywhere, and often near the coal and limestone which are necessary to reduce them to the metallic state. Pure iron, when found, is nearly white, very soft, quite malleable, and the most tenacious of all metals. It cannot easily be fused, and before it undergoes this process it assumes a soft pasty condition, in which one piece when hot can be hammered into another; *this process* is called *welding*. At a common temperature

iron attracts oxygen, thus forming *rust*, which is greatly increased by the presence of any acid vapour.

Q. What are the chief ores of iron?

A. *Hydrous peroxide*, from which the best iron is made; *red hematite; clay iron-stone*, found in coal formations; and *black or magnetic oxide of iron*, found in some mountain ranges.

Q. What is *cast* iron?

A. The melted iron which is drawn off when the metal is fused in the furnace.

Q. What is *steel?*

A. It is formed from refined iron by heating in contact with charcoal in close vessels.

Q. How many oxides of iron are there?

A. *Four*, viz. *protoxide; sesquioxide; black oxide;* and *ferric acid.*

Q. What are *iron pyrites?*

A. They are sulphurets of iron, and found in a native state.

Q. What are the *salts* of iron?

A. *Green vitriol*, called also more commonly *copperas;* and *carbonate of iron.*

Q. What is the metal called *chromium?*

A. It is a hard substance like cast-iron, upon which acids have little power, nor is it decomposed by water. Its best known compound is the colour called *chrome-yellow*, or *chromate of lead.*

Q. What are the properties of *nickel?*

A. It is a rare metal, considered by German miners as a false copper ore. It is white and malleable, and is also strongly magnetic. The chief use of this metal is in the manufacture of what is called German silver.

Q. Give some account of *zinc.*

A. It is an abundant metal, found with lead ores in many districts; it is of a bluish-white colour, which tarnishes slowly in the air. It is both brittle and malleable; the latter at a temperature between 250° and 300°.

Its salt, called *chloride of zinc*, is the most effectual deodoriser yet known.

Q. In what state is *copper* found?

A. In its pure or metallic state, but more commonly as *sulphuret of copper*, or *copper pyrites*.

It is very malleable and ductile; and an excellent conductor of heat and electricity.

Q. What oxides does it form?

A. *Two;* viz. *black oxide* of copper, which is the base of all its blue and green salts; and *red oxide* of copper, which is used for imparting a beautiful ruby colour to glass.

Q. Another useful metal in this class is *lead;* in what form is it most commonly found?

A. In that of *sulphuret of lead*, or *galena.*

This is an abundant and useful metal, of great specific gravity, and little elasticity.

Lead is slowly acted upon by soft or rain water; and is, consequently, a dangerous metal for water pipes, unless the qualities of the water are proved by experiment not to affect it.

The most important of its oxides is that of *red lead.*

It also forms a carbonate, which is *white lead.*

Q. What metals in the fifth class are the most deserving of notice?

A. Those of *tin* and *antimony.*

The former is soft and white, and is found in Germany, Malacca, and in large quantities in Cornwall. When heated above its melting point tin oxidises, and is converted into a white powder, used for polishing, and called *putty-powder.* Tin combines with copper and lead, forming compounds, or alloys of great value in the arts. It is very malleable, and *tin-foil* is made of $\frac{1}{1000}$th of an inch in thickness. It is a good conductor of heat and electricity.

Q. What is *antimony?*

A. It is an abundant metal of a grey colour, and very *brittle.*

An alloy of antimony with lead forms the type-metal of the printer; and it is used for this purpose because the casts of the letters made from it are sharp and defined.

Some of the compounds of antimony are employed in medicine.

Q. What is the characteristic of the metals of the sixth class?

A. That they are comparatively unchangeable; and resist oxidation in the fire. Gold and platinum are always found in the metallic state in the earth; and silver and mercury often so.

Gold is not affected by exposure to the air, nor do common acids produce any effect upon it.

Platinum is a valuable metal for its hardness; its infusible nature renders it particularly useful for the manufacture of vessels required by chemists for experiments depending upon great heat.

Mercury is remarkable as the only metal which is fluid at a common temperature; below 40° it becomes solid and can be hammered like lead. At 660° it boils and forms a dense vapour.

It is of great use in the arts in its alloys and compounds.

Q. Having thus briefly noticed most of the principal metals, it will be useful to conclude this Catechism by a few questions on the application of chemistry to agriculture. As a preliminary, then, to such considerations, define the difference between the *organic* and *inorganic* parts of a plant.

A. If any dry vegetable substance is subjected to a flame, the greater portion is consumed in the form of gases; this is called the *organic* part of the plant, while the ash which remains after the burning is called the *inorganic* part. Thus, the *organic* is said to be destroyed, the *inorganic* to remain.

Q. Of how many substances does the *organic* part of plants consist?

A. Of *four;* viz., *carbon, hydrogen, oxygen,* and *nitrogen.*

Q. What are the most abundant compounds of these four elements?

A. Woody fibre, starch, gum, sugar, gluten, and albumen.

Q. What substances compose the *inorganic* part?

A. *Potassa, soda, lime, silica, magnesia, alumina, oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid,* and *chlorine.*

Q. In what proportions are the substances in the organic part of plants generally found?

A. Carbon is nearly half the weight of the whole substance; oxygen more than one-third; and hydrogen a little more than the nitrogen.

Q. How are these elements supplied to plants?

A. By their food; which they receive through their roots and by the pores of their leaves.

Q. What nourishment is thus supplied?

A. The manures and other matters in the soil feed the roots; the action of the air affords nourishment through the leaves.

Q. Of how many parts is a plant composed?

A. Of three, viz.: the root, the trunk, and the leaf.

Q. What are the offices of each?

A. The *root* supports the plant, or tree, in the ground, and by spreading out its fibres in all directions, absorbs liquid food from the soil.

The *trunk*, or stem, consists of an inner pith, of wood surrounding it, and of the bark which covers the whole. In the pith are a number of cells, which communicate with the air horizontally through the apertures of the outer bark. The wood and inner bark are made up of small vertical tubes, which convey nourishment between the root and the leaves.

The leaves consist of the fine extremities of the twigs, branching out into many delicate fibres; the green covering of these, when examined through a microscope, is found to be full of pores, particularly on the under surface of the leaf. These pores communicate with the fibres, thence with the twigs, branches, stem, and root.

Q. What is the chief nourishment of a tree?

A. Its *sap*, which is almost always circulating through the tree, the only time during which it is stationary being when it is frozen. This sap is produced in the spongy part of the root, and ascends through the cellular vessels of the stem until it is spread over the interior of the leaf by its fibres. When it has thus reached the extremity of its course it is again returned to the bark and root by means of the vessels in the leaf beneath the fibres.

Q. What other nourishment do the leaves derive?

A. That which they inhale in a gaseous form from the atmosphere. In the day-time the leaves continually absorb carbonic acid gas from the air, particularly in the sunshine, and give off oxygen; but at night they retain the oxygen and give off carbonic acid. This latter gas, when present in the air to the amount of seven or eight per cent., exercises a pernicious influence on animal life.

Q. Is carbon supplied to the plant in any other way?

A. Yes: it is also in part supplied to the roots by the *humus*, or decaying vegetable matter of the soil. This is sometimes called *ulmic acid*, and is a compound of carbon and water.

Q. What elements of food are necessary to plants?

A. Carbonic acid, water, and ammonia, and these must be supplied both by the air and the soil; while, in addition, saline and earthy substances are imparted by the soil alone.

Light and heat are also requisite to the growth of plants, and the former is essential to the action of their colouring matter.

Q. Is *nitrogen* found in plants?

A. Yes: ammonia and nitric acid supply it to the plant; ammonia, like water, enters into contact with other bodies in a great number of combinations. Ammonia and its compounds are very soluble in water, and hence it is to be found at all times in rain water.

Q. At what season of the year is ammonia prevalent in rain, and why?

A. In the summer, because rain being then less frequent, the accumulation of ammonia between the showers is greater.

Q. What are the stages of germination from a seed to a plant?

A. When the planted seed begins to sprout, it sends forth a shoot into the air and a root into the soil. At this stage of its growth it feeds on the starch and gluten contained in the seed. The starch in the seed is rendered soluble by a substance called *diastase*, and its nourishment is thus conveyed to the shoot and root of the plant. At this stage the starch becomes sugar; the plant produces leaves, the sugar is changed into fibre and forms the stem. When the starch and gluten are exhausted, the plant is ready to continue its nourishment from the air and the soil.

Q. You have said that the principal nourishment of plants consists of *woody fibre*, *starch*, *gum*, *sugar*, *gluten*, and *albumen;* describe these substances.

A. *Woody fibre* is the casing of the tree within the bark, and in which the cells that convey nourishment to the tree or plant are placed.

Starch consists of carbon and water, the proportions of each varying in different substances.

Gum may be obtained by raising starch to a high temperature, or by digesting it in sulphuric acid. Gum thus formed is found in the sap of plants.

Sugar exists in certain roots, trees, and plants, and generally consists of forty-eight parts of carbon and sixty-six of water.

Sugar is formed artificially by boiling down any starchy substance for some time in water, and then acidulating the mass with sulphuric acid.

Gluten is a close adhesive matter of an oily nature, quite insoluble in water, and only partly so in alcohol.

Albumen is a white vegetable substance like the albuminous part, or white, of an egg. It can be dissolved in water, but becomes solid and hard at a moderate heat.

Q. What other substances are produced in plants by the assimilation of their food?

A. Those which are *mucilaginous*, and can be extracted by water from oily seeds, &c.

Pectine, which is a substance found in pulpy fruits, such as peach, apricot, &c., and in roots, such as turnip, carrot, and parsnip. In these it takes the place of starch, and contains less hydrogen and more oxygen.

Another group of substances may be termed the *fatty group*, and consist of fat, oil, wax, turpentine, and resin.

Wax covers the leaves and flowers of many plants; the bloom on fruits is also a thin film of wax. Water does not affect it.

Turpentine and *resin* abound in trees of the pine kind, and, like wax, are insoluble in water, and very combustible.

Q. Describe the use of the *inorganic* substances which have been enumerated as entering into the constitution of plants.

A. The *ash* or inorganic matter of a plant is as essential to its growth as any of the organic elements. But care must be taken to apply the *proper quality* of ash to render the soil favourable to the growth of the particular plant to be cultivated thereon. The quantity of inorganic matter varies in different parts of the same plant as well as in different plants.

A crop of corn returns a larger portion of mineral matter to the soil in the fermented straw, than the soil loses in the grain. The same with the decayed leaves of the trees in autumn, which then return to the soil a large portion of the inorganic matter imbibed by the roots during the spring and summer.

Q. As the inorganic matter of a plant draws off a certain portion of nourishment from the soil under the various forms of matter which have been mentioned, what course is necessary to be adopted in the cultivation of the land?

A. It is necessary to restore an equivalent to the land in the form of *manures*, or so to manage the crops by

rotation, that the soil should not be deprived of any mineral element necessary to the growth of vegetation; and that the inorganic matter carried off by one crop may be restored by others before the time arrives for the first crop to be grown again.

Q. Of what *two* principal portions are soils composed?

A. Of *organic* and *inorganic.*

Q. Of what does the organic consist?

A. This portion, called the *humus*, consists of decayed remains of animal and vegetable matter. In peaty soils a large proportion of organic matter is found, while in rich and well-cultivated lands only one-twentieth of their whole weight of organic matter is found.

Q. Is a soil fertile in proportion to its amount of humus?

A. No: it is only of use when it supplies plants with root food in the form of carbonic acid; if it mingles with water it then becomes injurious to the plant, because shows that there is not oxygen enough to convert tl. humus into carbonic acid.

Q. How is a stagnant and marshy soil injurious to vegetation?

A. For the above reason, that humus in solution with the water of the soil deprives the plants of their necessary oxygen; but when the damp soil is drained, and air freely admitted, the marsh soon becomes a fruitful field.

Q. What are the *inorganic* parts of a soil?

A. *Soluble saline* substances, and the *earthy* or *insoluble.*

Q. Of what do the *saline* substances consist?

A. Of common salt, soda, lime, potassa, calcium, and nearly all the ingredients contained in the ash.

Q. What are the *earthy* or *insoluble?*

A. They consist of *three* principal ingredients, viz.: *silica*, or sand; *alumina*, mixed with sand, as *clay;* and *lime*, as *carbonate* of *lime*, *chalk*, &c.

Where the soil is of a *red* colour there is *oxide of iron;* *if a soil contain* more than five per cent. of carbonate of

lime it is called *marl;* if more than twenty per cent., a *calcareous soil.*

Q. How are soils originally produced?
A. By the disintegration, or gradual crumbling away of rocks, caused by the action upon them of water, wind, frost, and other chemical agents.

Q. What are the general qualities of certain soils?
A. *Sandy* and *marly* soils are heavy; *clays* and *peat* absorb and retain moisture: they are a cold ungenial soil, where a plant cannot obtain the amount of heat requisite to its growth on account of the continual evaporation. Hence the necessity for draining.

An entirely clay or peat soil contracts with heat, and thus prevents the air from reaching the roots of plants, and retards their growth. But a certain amount of clay is useful in a dry soil, as it absorbs the dew in summer, and retains the moisture for some time.

Q. What are the requisites of a good soil?
A. That it should contain all the elements essential to the growth of a plant in a proper proportion.

Q. How is this to be effected, since it is not found naturally?
A. By the artificial application to the land, in their proper proportion, of those elements in which it is found deficient; *ex. gr.* one soil may contain soda, and be deficient in the salts of lime; and so on for other ingredients.

This deficiency should be supplied for a time either by planting the land with those crops which are suited to the predominant element in the soil, or by the artificial supply of those elements which are wanted for the growth of general crops.

Q. How can soils be improved?
A. By *draining, ploughing,* and *manuring.*

Q. What are the advantages of draining?
A. Damp lands are cold and unproductive because the constant exhalation of vapour prevents the sun from exercising a due influence in warming the land. An excess

of water, moreover, washes away the subsoil, and dilutes all the inorganic properties of the land to too great a degree. Draining is a remedy for this, as the land then receives its necessary amount of warmth, the air penetrates it more freely, and the properties of the soil are enabled to exercise their proper influence.

Q. What depth of draining is requisite for different soils?

A. Near the surface, if the soil is clay with a sand or gravel subsoil; if the soil is sandy with a subsoil of clay, the drain should be *in* the clay.

Q. What are the advantages of ploughing?

A. Water, air, and other gases are brought into contact with the roots by means of ploughing; the soil is lightened, and vegetable matter more generally decomposed and diffused.

On drained land no ploughing should take place till some time after the draining has been done.

Q. What is the principal object of manures?

A. To restore to the land those fertilising qualities which have been taken from it by crops and animals.

Q. Into how many classes may manures be divided?

A. Into *three: vegetable, animal*, and *mineral.*

Q. What is the use of *green* vegetable manure?

A. Vegetable manure, or *green manuring*, serves to loosen the land, and reduces the organic substances to a fit state for the nourishment of the roots.

Green manuring produces a rapid effect upon the soil. Where it is extensively practised a crop of mustard, rye, or some other green plant is sown, and when partly grown is ploughed into the soil. The juices of the plants soon ferment, and ammonia and nitric acid are thereby produced for the nourishment of the intended crop.

The cleanings of ditches, parings of banks, &c., collected into heaps and allowed to decompose, form a valuable green manure; as does also sea-weed.

Q. What are the usual components of *dry* vegetable *manure?*

A. Straw, sawdust, bran, grains, bruised rape-seed, charcoal powder, soot, peat, and tanners' bark, may all be applied as manure, but most of these substances require the addition of some fermenting matter, such as urine, before they are in a condition to fertilise the soil.

Q. What is the chief merit of *animal manures ?*

A. This class is the most efficient on account of the large amount of nitrogen which they contain in the form of ammoniacal salts.

Q. What animal substances are commonly employed?

A. *Bones*, which are used either pulverised or bruised; in the latter case, decomposition is slower, but the benefit more permanent. Bones reduced to powder by the action of dilute sulphuric acid form the most valuable manure for turnips.

Flesh, blood, parings of skin from tan-yards, *horns, hair*, and *wool*, are all valuable manures, when they can be obtained.

Fish forms the staple manure in some districts, and crushed *shell fish* is valuable on account of the mixture of lime in its composition.

The *animal refuse* of sugar refineries is also an excellent manure.

Solid and *liquid excrements* all form manures of the greatest value. *Horse dung* ferments rapidly, and imparts heat as well as nourishment to the plant; when mixed with other manures it soon raises them to a state of fermentation.

As a general rule that kind of animal manure is most effective which is returned to the soil on which the crop for the food of the animal producing it has been raised.

Thus, the dung of pigs fed upon peas and potatoes is the best manure for a field growing peas and potatoes.

Nightsoil and urine are the most effective fertilisers.

The dung of *pigeons*, and *sea-fowl*, or *guano*, mixed with coal ashes, sea-sand, or gypsum, is also a most active manure.

All *liquid* manure is also most valuable, and should be carefully preserved for farming purposes in tanks.

Q. What are the principal *mineral* manures?

A. *Lime* is the most important, *potash* and *silica* rank the next.

These manures are in great part applied to the land by means of the *ashes* of plants which produce the above-named substances. The ashes of straw crops always contain *silica* and *potash;* *lime* forms a principal ingredient in the ashes of pea-haulm and clover stalk.

Q. What are the principal uses of *lime* in a soil?

A. It gives body and tone to a soil, decomposes various organic substances, and renders others soluble. On clay land that has been recently drained it is particularly valuable, and also when properly applied to pasture and arable lands.

Q. In what *crops* is *sulphate of lime* applied with advantage?

A. To clover, pea, and bean crops.

Q. What other mineral manures are employed in agriculture?

A. *Sulphate of magnesia*, as a top-dressing for wheat.

Sulphate of soda, for turnips and potatoes.

Chlorine of potassium, for grass land.

And *nitrates of potassa and soda*, for young crops of corn and grass.

Q. Upon what principle should the rotation of crops be conducted?

A. Upon the principle that no component quality of a soil necessary for vegetation should be exhausted by the crop grown upon it.

Different plants draw from the soil different proportions of the matter contained in it. Such a succession, therefore, of crops should be raised that no two requiring principally the *same* kind of food, should be grown successively on the same land.

Q. What is the general system of rotation?

A. Supposing the soil to possess the proper qualities in their due proportions, and to be properly prepared for the *growth of the* crops, then the course of culture should

begin with a *potash* plant, such as turnips or potatoes ; next, a *silica* plant, such as wheat; then a *lime* plant, such as peas or clover.

Another plan of rotation is to begin with *wheat*, next, *turnips*, then *barley*, *seeds*, *oats*, and, finally, *potatoes*.

Q. Of what benefit is a clover crop to the land ?

A. It helps to fertilise the soil and to prepare it for a corn crop.

Q. What is *fallowing ?*

A. It is allowing land to remain uncropped for a season, during which, by manuring and ploughing, its resources are revived, and it is again fitted for cultivation.

THE END.

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